THE UNITED STATES
STRATEGIC BOMBING SURVEY

THE GERMAN ANTI-FRICTION BEARINGS INDUSTRY

EQUIPMENT DIVISION

JANUARY 1947

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This report was written primarily for the use of the U. S. Strategic Bombing Survey in the preparation of further reports of a more comprehensive nature. Any conclusions or opinions expressed in this report must be considered as limited to the specific material covered and as subject to further interpretation in the light of further studies conducted by the Survey.

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Foreword

The United States Strategic Bombing Survey was established by the Secretary of War on 3 November 1944, pursuant to a directive from the late President Roosevelt.

The officers of the Survey were:

Franklin D'Olier, Chairman.
Henry C. Alexander, Vice-Chairman.

George W. Ball,
Harry L. Bowman,
John K. Galbraith,
Rensis Likert,
Frank A. McNamee, Jr.,
Paul H. Nitze,
Robert P. Russell,
Fred Searls, Jr.,
Theodore P. Wright, Directors.

Charles C. Cabot, Secretary.

The Table of Organization provided for 300 civilians, 350 officers and 500 enlisted men. The Survey operated from headquarters in London and established forward headquarters and regional headquarters in Germany immediately following the advance of the Allied armies.

It made a close examination and inspection of several hundred German plants, cities and areas, amassed volumes of statistical and documentary material, including top German government documents; and conducted interviews and interrogations of thousands of Germans, including virtually all of the surviving political and military leaders. Germany was scoured for its war records which were found

sometimes, but rarely, in places where they ought to have been; sometimes in safe-deposit vaults, often in private houses, in barns, in caves; on one occasion, in a hen house and, on two occasions, in coffins. Targets in Russian-held territory were not available to the Survey.

Some two hundred detailed reports were made. During the course of its work, the Survey rendered interim reports and submitted studies and suggestions in connection with the air operations against Japan.

While the European War was going on, it was necessary, in many cases, to follow closely behind the front; otherwise, vital records might have been irretrievably lost. Survey personnel suffered several casualties, including four killed.

The Survey studied the effects of the air attack on Japan and further reports have been submitted to the Secretary of War and the Secretary of the Navy.

THE GERMAN ANTI-FRICTION BEARINGS INDUSTRY

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THE GERMAN ANTI-FRICTION BEARINGS INDUSTRY

INTRODUCTION AND SUMMARY

1. As essential components of virtually all the mechanical devices used in the dynamic warfare of today, anti-friction bearings occupy a key position in a modern war economy. Planes, tanks, motor vehicles, weapons, electrical equipment, precision instruments, and plant machinery all depend on bearings for speed and efficiency of performance.

2. In 1943, the German anti-friction bearings industry was known by the Allies to be heavily concentrated in Schweinfurt; the VKF and Kugelfischer plants in that town, together with a few others at Stuttgart, Steyr, and Berlin accounted for the bulk of the industry's production in Germany. Accordingly the bearings industry was selected as a target system for the Allied Air Forces, and beginning in the summer of 1943 a series of forty air raids, aimed at bearings plants in Germany, Austria, France and Italy, was carried out, with at least eleven other raids on areas in which bearings plants were located. In all, over 12,000 tons of bombs were dropped on these targets by the Eighth, Fifteenth, and Royal Air Forces. Almost two-thirds of this tonnage was aimed at Schweinfurt.

3. Building destruction in these raids amounted to almost half the pre-raid floor space of the industry, while the equivalent of another half was heavily damaged. Damage to machine tools was not proportionate to damage to buildings; machine tools destroyed equalled 12 per cent of the original inventory, and those damaged an additional 30 per cent.

4. The intensity of the raids and their accuracy varied greatly. Small plants such as Annecy and Ebelsbach were completely knocked out; medium plants such as Steyr or VKF Berlin were put out of operation for considerable periods of time, and large plants such as those at Schweinfurt had production partially disrupted.

5. It proved more difficult to put factories out of operation than had been foreseen. The susceptibility of machine tools to damage was not very great; fire proved more effective than blast. Stocks of raw materials and semi-finished bearings could not be harmed irrecoverably. Finally, even hits on vital processes were not sufficient to put a whole plant out of commission, as had been expected. The organization of a bearings plant into departments, each carrying through complete manufacture of one component, was such that even though production of one or more components was halted, the other manufacturing processes could continue nevertheless and final assembly made from stocks. In addition, much machinery in one department could be quickly adapted for use in another, so that even though a vital process was destroyed substitute machine tools were readily available.

6. Nevertheless, the weight of attack caused a drop in bearings production in April, 1944 to less than 50 per cent of the pre-raid level. Recovery reattained the pre-raid level by September 1944, one year after the first attacks. The total loss of production during the period of bombing was the equivalent of two to three months' output at the pre-raid rate. This loss was caused largely by the intermingled factors of direct bomb damage and the German policy of dispersal with its attendant immobilization of machinery and equipment.

7. German plans contemplated a great expansion in armaments production during 1944. In order to meet the increased bearings requirements demanded by this program, plans had been drawn up at the time of the first attacks on Schweinfurt to double the 1943 output of the bearings industry in the following year. Although this program could not be carried out, and there was actually a decrease in the output of bearings, shortages of bearings did not delay or halt armament production.

8. Failure to attain the planned level of bearings production did not interfere with finished armament production because of the energetic countermeasures taken by the Germans. An aggressive program of redesign of armaments so as to eliminate anti-friction bearings wherever they were not absolutely necessary materially reduced requirements. Stocks of finished bearings in both the bearings plants and in user plants, orders and deliveries were strictly controlled so that essential users were protected. Vigorous production measures, dispersal from the large centers of production to numerous small plants, the construction of underground plants, the bomb proofing and erection of blast walls around vital machinery, and the rapid repair or replacement of damaged or destroyed machinery and equipment, enabled production to return to adequate levels before the cushion provided by stocks and the shortening of the pipeline between producer and user plants had ceased to exist.

9. The rapid restoration of production in bearings plants was materially aided by the availability of machine tools ordered as part of the expansion program, and by the appointment of a czar for the bearings industry with full authority to requisition machines, plants, personnel or services from other industries. In this appointment, it may be noted, a principle of administrative action was established which, when extended to oil, steel and aircraft, was ultimately to be embarrassing to the orderly planning and scheduling of war production.

10. The Germans were thus able to make good their boast, "Es ist kein Geraet zurueck geblieben weil Waelzlager fehlten" (no equipment has been held up because of a shortage of bearings).

PART ONE. THE GERMAN ANTI-FRICTION BEARINGS INDUSTRY UNDER ATTACK

CHAPTER ONE. THE SELECTION OF THE BEARINGS INDUSTRY AS A TARGET SYSTEM.

Background of the Selection

1. Between August 1943 and December 1944, a systematic aerial campaign was carried on against the German anti-friction bearings industry. Aimed simultaneously at aircraft and bearings, the campaign was the first in the air forces' separate military operation, or air war, against the enemy. Its mission, in the words of the Casablanca directive, was:

> "...the progressive destruction and dislocation of the German military, industrial, and economic system to a point where...capacity for armed resistance is fatally weakened."

2. Before June 1943 that basic mission was in preparation. Operational factors limited what the air forces could undertake; with relatively few bombers of circumscribed range, blows at the heart of the enemy's economy were impractical. But early experimental raids against French and Belgian targets in the fall of 1942 proved that daylight precision bombardment was practicable, despite the previous failure of the German and Royal Air Forces to use the method successfully.

3. From the first, however, the air forces had to devote their efforts to tactical and diversionary targets as well as to preparation for the air offensive. The anti-submarine campaign was the most elaborate of these programs. The second was the counter-air offensive, from June 1943 to May 1944. The tactical purpose of assuring air superiority for D-Day operations was here linked with the necessity of achieving air superiority over enemy territory for the carrying out of the strategic bombing program. Destruction of planes in the air and on the ground was joined with systematic attack on factories assembling aircraft and producing airframes and components.

4. The counter-air offensive in itself, however, was not shaped to accomplish the chief aim of the American theory of precision bombing. A careful selection of a particular industrial system or systems whose destruction would bring about the dislocation of the enemy military economy was demanded. In choosing such a system, the capabilities of the available air force were as decisive a criterion as the merits of the proposed system. Oil, the eventual choice, was thus not possible in 1943. Other alternatives--aluminum or electric power--were eliminated for this reason, because of remoteness from the front lines, or because of substitute sources of supply.

5. Bearings offered the most promising method of striking a serious blow at German war economy as a whole, without diverting any major effort from the task of assuring air superiority. Indeed, it was hoped that attacks on bearings plants would reinforce and guarantee the results of the raids on aircraft plants, since aircraft were the major users of bearings. What, then, were the characteristics of the industry that led to its adoption as the focus of attack?

6. Bearings Industry as a Target System. Anti-friction bearings promised far-reaching results with a minimum of effort. Three general suppositions underly the choice of the industry as a target system:

a. The industry's pivotal place in the economy.
b. Its concentration.
c. The difficulty of recovery.

7. The Pivotal Place of Bearings in the Economy. Vital to the manufacture of armaments, bearings seemed to provide an opportunity through which we could, by cutting the supplies of one single component, create far greater repercussions in the industries utilizing it. In the highly mechanized modern war machine, the field affected would be wide and comprehensive, including the manufacture not only of aircraft but also machinery and equipment.

8. These many and varied users of bearings would, it was felt, begin to feel the pinch of shortened supplies within a month of a successful attack on the centers of production. This belief rested upon Intelligence analyses indicating that delivery to customers was on a hand-to-mouth basis and that these customers carried only small stocks of finished bearings. The combination of these two factors indicated an industry lacking in depth; disruption of its output would affect operations at an early date in the aircraft industry and others using bearings, and soon thereafter in the front lines themselves.

9. Concentration of the Industry. The highly desirable knock-out blow at the bearings industry was considered relatively easy to deliver because of the concentration of production in a few main centers. Plants in six cities were believed to be responsible for 73 per cent of the entire output of bearings available to the German economy, even including supplies obtained from neutrals or satellites. This 73 per cent was broken down as follows:

Schweinfurt	42 per cent
Stuttgart	15 per cent
Paris & Annecy	9 per cent
Leipzig and Berlin	7 per cent

The importance of these centers was presumed to be increased by their specialization in military bearings.

10. Difficulty of Recovery. The most important factor determining recovery is the ability to reconstruct, but equally crucial is the possibility of the effect of the raids being absorbed during the reconstruction and repair period. Analyses of the German situation indicated that the "cushion"--the alternate ways of absorbing effects of raids--could be broken through.

11. One element of the "cushion" was the lavish use of bearings in German designs, the result of the industry's long existence and excellent salesmanship. German planes, tanks, and machines were assumed to contain more anti-friction bearings than comparable British and American models. The possibility of eliminating these uses was discounted, however, in the expectation that changes in design would require at least six months and probably a year. Technical difficulties would keep the savings in bearings consumption small, and localize them in industrial rather than military equipment.

12. Stocks of semi-finished components in bearings plants were estimated as sufficient for about six months' production. An effective attack on a bearings plant should result in destruction or serious damage to the bulk of these stocks, removing the possibility of their serving as a cushion during the post-raid period.

13. Other possibilities of cushion were similarly ruled out. The already short pipeline -- one month from producer to consumer -- could not be cut farther. Deliveries to essential war industries could to some extent be kept up by a cut in allocations to non-military users, but the total thus saved would be small. At the same time, taking bearings from, say, a locomotive factory, would still have an adverse effect upon the war economy itself in the long run.

14. It was anticipated that Germany would make an effort towards fuller utilization of alternate sources of supply. Within the lands under German rule this would affect chiefly the French factories, which contributed nine per cent of the total Axis production in 1942. Diversion of more raw materials and machine tools to their assistance would enable them to expand their operations somewhat. Imports, chiefly from Sweden, could be slightly enlarged as well. The total effect of both measures was not though likely to be great, however; an estimate classed as "generous" put the possible increase at five per cent.

15. The "Cushion", then, was thought insufficient to tide the industry over the period between destruction and reconstruction of plant. This period was likely to be protracted by difficulty in repairing machines; repair time was estimated at six to 12 months.

16. Expected Outcome. Such were the considerations that underlay the decision to attack. Attacks on production in just four cities --

Schweinfurt, Berlin/Erkner, Stuttgart, and Leipzig -- would, if successful, eliminate 64 per cent of Germany's sources of bearings supplies. Recovery would be slow, with reconstruction extending over the period of a year. The combined effects of destruction of installations and of semi-finished and assembled stocks would lead to an estimated loss of nine months' production, a loss which could be offset by compensating factors of cushion to only a small extent. Pipelines were already short, stocks, in hands of consumers were small, and savings through redesign of military equipment would take too long to be realized. Better utilization of alternate sources of supply in the conquered or neutral countries would yield a paltry five per cent increase.

17. The lack of depth to the industry meant that damage to the bearings producers would soon be shared by its consumers. Non-military users would suffer most, with less critical military items such as trucks next in line. A nine-months' loss of output, however, would be bound to reach even to producers with top priority. No counter-measures would be able to avoid a 30 per cent drop in armament production as a consequence of successful attack.

CHAPTER TWO: THE TARGET INDUSTRY ON THE EVE OF ATTACK

Use-Patterns for Bearings

1. As essential components of virtually all the mechanical devices used in modern warfare, anti-friction bearings occupy a key position in any modern war economy. A glance at the following table shows the extensive use to which they were put by the German manufacturers of aircraft, tanks, weapons, ships, and military vehicles, who together purchased almost half the industry's output. Accessories for armaments demanded another high percentage of bearings. In addition, into the factories producing these arms and other munitions went machinery containing still other bearings.

TABLE 1 WARTIME USES OF ANTI-FRICTION BEARINGS
December 1943

Industry	Consumption of Bearings	
	Number (in thousands)	Per cent of total
Aircraft	2,395	31.4
Tanks	300	4.0
Motor Vehicles	310	4.1
Weapons and Naval	266	3.5
General Equipment:	3,745	49.1
Electrical	(1,500)	(19.7)
Machinery	(1,260)	(16.5)
Precision Tool & Optical	(110)	(1.4)
Other	(875)	(11.5)
Export	600	7.9
TOTAL PRODUCTION	7,616	100.0

(Source: Sonderring Waelzlager)

As this table shows, needs for bearings were enormous in aircraft manufacture. Modern advances in aviation designs have entailed the use of highly specialized bearings to overcome friction, enabling power units with low horsepower weight ratios to carry heavy loads at high speeds. For example, the air frame for a single Ju-388 bomber, a medium type, required 1,056 anti-friction bearings. Its motors and instruments called for hundreds more. Almost every aircraft part had a specific bearings need: propellers, variable pitch propellers, superchargers, pump drives, and reduction gears, as well as the bomb sights, automatic pilot, and other control instruments.

2. Tanks and motor vehicles capable of high speeds at heavy loads also demanded anti-friction bearings throughout their construction. Likewise, weapons of all types depended on bearings for their accuracy and wear. The 88-mm flak gun used 47 anti-friction bearings, a 200-cm searchlight used 90.

TABLE 2

GERMAN ANTI-FRICTION BEARINGS INDUSTRY

VALUE DELIVERED 1938-1944
(Thousand of RM)

	1938	1939	1940	1941	1942	1943	1944
VKF (Total)	91,885	92,700	95,256	101,530	108,696	117,508	90,116
Schweinfurt	-	-	-	-	-	-	-
Cannstatt	-	-	-	-	-	-	-
Erkner	-	-	-	-	-	-	-
Sub-Total	-	-	-	-	-	-	-
Puerstein	600	687	1,003	1,021	982	-	-
TAG (Total)	45,196	54,762	59,502	67,530	79,721	85,854	97,530
Schweinfurt	40,733	47,633	49,075	55,415	66,566	-	-
Elberfeld	3,446	5,542	7,923	8,821	9,550	-	-
Berlin (NDK)	1,017	1,587	2,504	3,294	3,605	-	-
Steyr	3,400	5,380	8,268	10,061	16,599	32,851	36,360
DKF	6,658	10,084	11,399	10,838	12,743	17,246	17,004
Muller	2,437	2,671	3,452	3,793	3,836	4,200	7,438
Kling	1,637	1,862	1,804	1,931	2,320	3,600	5,044
5 Small firms	2,668	3,316	3,490	4,010	5,799)	15,618	26,880
(other small firms (est)	1,335	3,316	3,490	4,010	3,480)	-	-
Total	155,216	174,091	186,661	203,703	233,194	276,877	280,372

(Source: Fachgruppe Waelzlager und Triebwerke, und Sonderring Waelzlager)

3. The general needs of an economy geared to war production resulted in a vast demand for bearings. More and more machines, electrical equipment, and installations of all kinds requiring anti-friction bearings were needed. Indeed, as the above figures show, the general equipment industries, which included the production of definitely military items as well as activities essentially civilian in nature, required more bearings than the industries producing aircraft, tanks, motor vehicles, and weapons.

4. An important quantity of bearings, which were exported to Germany's allies and dependents, was necessary for the maintenance of productive activity in armament and essential civilian industries in the conquered and satellite countries.

5. Anti-friction bearings were by no means a wartime development. Before the industry went to war, the pattern of bearing-use in industry was as follows, according to estimates by German plant officials:

TABLE 3

PEACETIME USES OF ANTI-FRICTION BEARINGS
(1933-1935)

Industry	Per cent of output
Motor Vehicles	30/35
Agricultural Machinery	15/20
Electrical Equipment	15/20
Machines & Machinery	10
Precision Instruments	5/10
Railroad Equipment	2
Shipbuilding	1
Small & Repair Needs	7
Export	10

With the stepping up of war preparations, industry converted to armament production and expanded rapidly. Accompanying these changes requirements for bearings increased steadily, ultimately reaching a level four times as great as normal peace-time; the production of some types of peace-time equipment, such as agricultural machinery, became insignificant, and bearings capacity released from such needs was diverted to military equipment production.

Functions and Construction of Bearings

6. This war and peace-time demand for anti-friction bearings is normal in a mechanical civilization. Modern machinery stresses power, speed, and endurance, and a chief obstacle to all three is friction between moving parts. As the name implies, "anti-friction" bearings are

the machine designer's prime way of avoiding friction and its drain on power, speed and endurance.

7. Bearings fall into two general categories; plain or friction bearings, and anti-friction bearings. Although bearings have been brought to a high stage of development in modern machines, the principles upon which they operate were utilized in very primitive equipment. The plain bearing is simply a cylindrical sleeve or bushing which separates a rotating from a non-rotating part--for example, a wheel from a shaft--and prevents these essential parts from being worn away by taking up the friction itself. In modern industrial use, the plain bearing has a prescribed clearance, is used with a lubricant which reduces some of the friction, and frequently consists of two sleeves or rings fitting into each other and separated by a film of oil.

8. The anti-friction bearing ("Waelzlager") employs balls or cylindrical rollers to separate the rotating rings. It usually consists of four parts of components: the inner ring, the outer ring, the set of balls or rollers, and the retainer or cage that separates the rolling parts and holds them in position. (Figures 1 and 2) Like plain bearings, anti-friction bearings are used with a lubricant. The advantage of anti-friction bearings over plain bearings is primarily the minimizing of friction between rotating parts: less power input is required, so that higher speed and heavier loads are possible, resistance to wear is increased, and maintenance requirements are diminished. It should be pointed out that in some applications the advantages are not very marked, and equipment can be designed to give as good performance with plain bearings at certain points as with anti-friction bearings throughout. However, once a design of a part embodying anti-friction bearings is in production, the substitution of plain bearings will generally bring inferior results.

Types of Bearings

9. The most important types of bearings, and the proportions in which they were produced in Germany during July 1943 are as follows: (Figure 2).

TABLE 4 BEARINGS PRODUCTION BY TYPES
July 1943

Type	In Thousands	Per cent
Ball Bearings (Kugellager)	7,088	84.6
Cylinder Roller Bearings (Zylinder lager)	654	7.8
Tapered Roller Bearings (Kegellager)	301	3.6
Spherical Roller Bearings (Tonnenlager)	35	.4
Thrust Bearings (Scheibenlager)	293	3.5
Other	8	.1
	8,379	100.0
Needle Bearings	1,169	

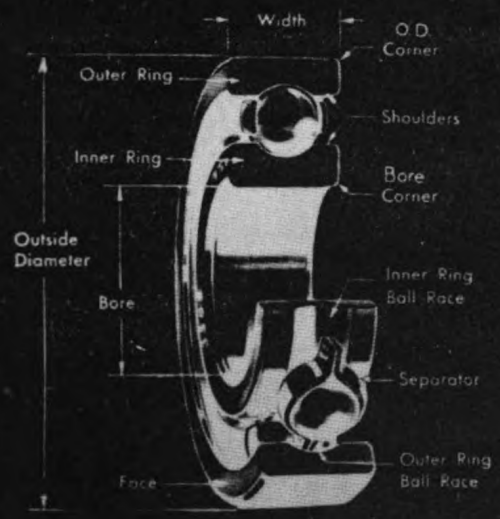
(Source: Sonderring Waelzlager)

Bearing Parts and Their Names

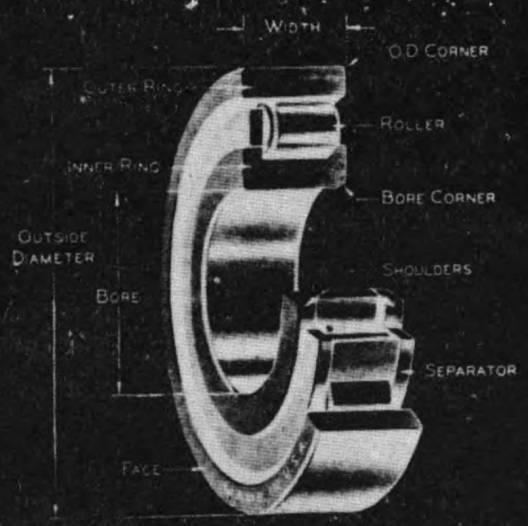
The parts common to all standard ball and roller bearings have, for the purpose of this manual, been given names as shown below.

Basically all anti-friction bearings consist of two hardened steel rings, the hardened balls or rollers and separator. A number of variations of these types are in use. Some types, such as Needle roller bearings may be used without an inner ring, the rollers fitting directly upon the hardened shaft. Needle bearings have no separator.

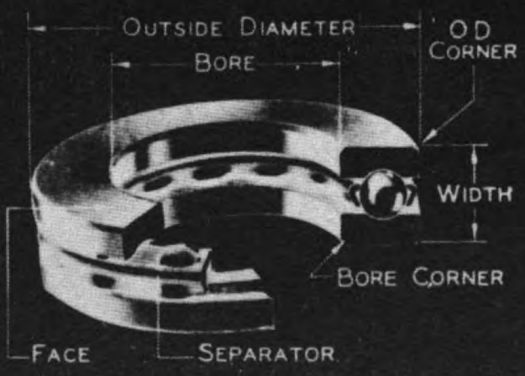
Ball Bearing



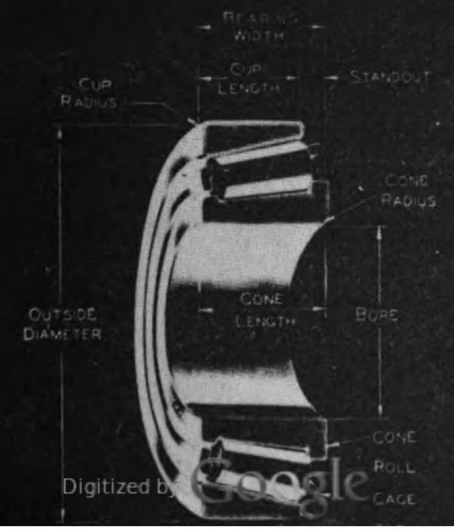
Straight Roller Bearing



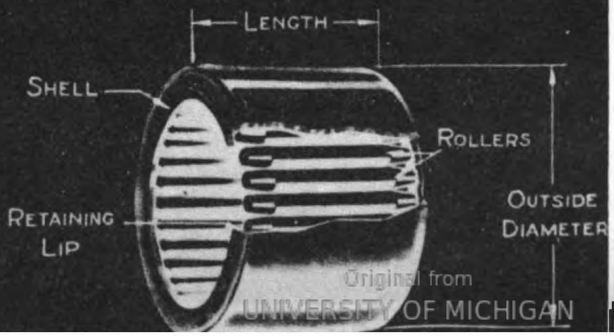
Ball Thrust Bearing



Tapered Roller Bearing



Needle Roller Bearing



Types of Anti-friction Bearings

Ball Bearings

*1. Duplex bearings are specially face ground for use in pairs.

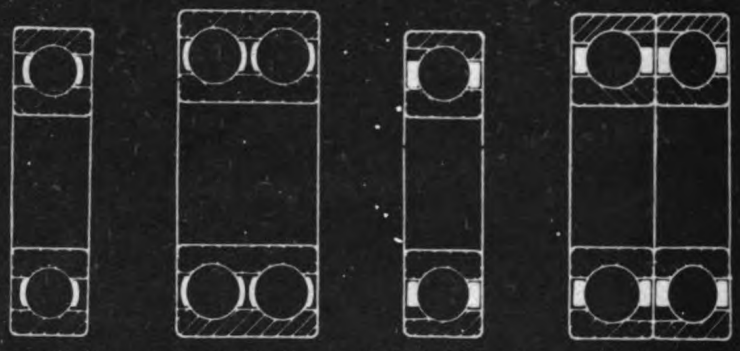
*5. Snap Ring bearings are used both with and without shields.

*6. Shields may be on either one or both sides.

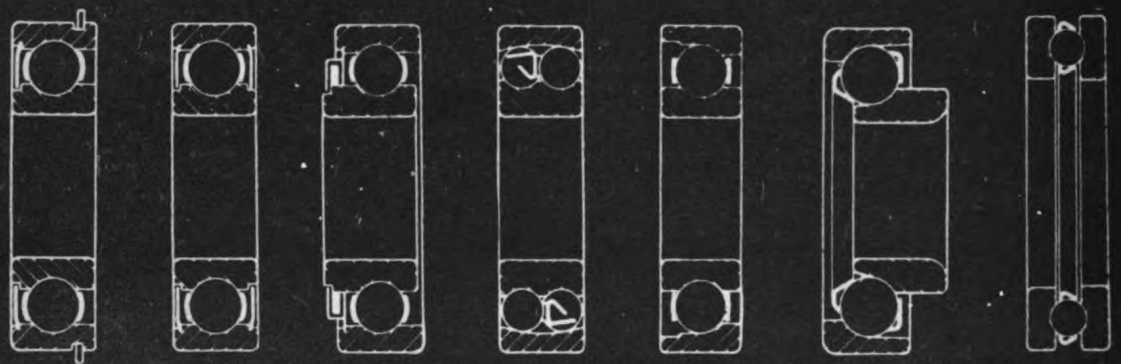
*7. Sealed bearings may have seals on both sides—are then wider.

*9 & 10. Magneto and Front Wheel bearings are separable.

*11. Ball Thrust bearings are treated separately on pages 16 and 17.



1. Single Row 2. Double Row 3. Radial-Thrust *1. Duplex



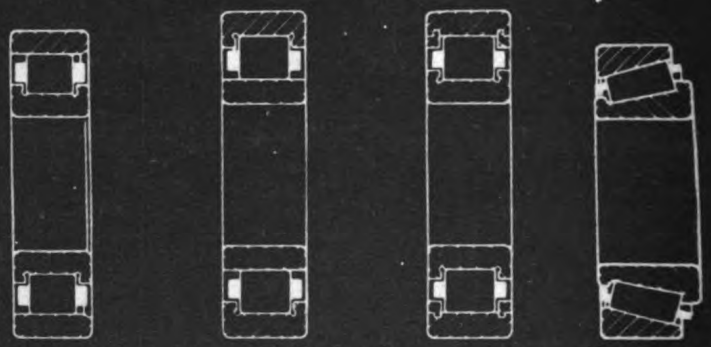
*5. Snap Ring *6. Shielded 7. Single Seal 8. Self-aligning *9. Magneto *10. Front Wheel *11. Ball Thrust

Roller Bearings

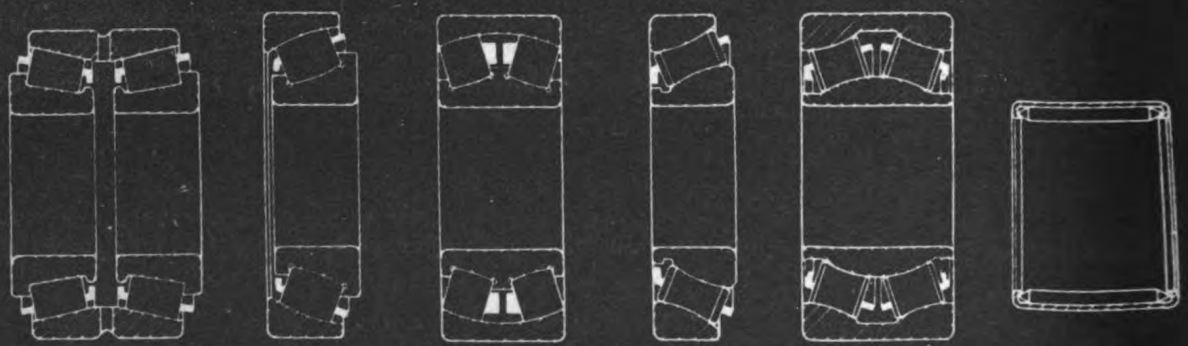
*1, 2, 4, 5, 6, & 8. These bearings are all separable either as to inner or outer rings.

*5. Double Row tapered roller, adjustable through cones. Also made adjustable through the cups.

*10. In some cases needle bearings may have inner rings which are separable.



1. Straight Roller Separable outer ring 2. Straight Roller Separable inner ring 3. Straight Roller Non-separable 4. Tapered Roller



5. Tapered Roller Double Row 6. Barrel Roller 7. Barrel Roller Double Row 8. Concave Roller 9. Concave Roller Double Row 10. Needle Roller

10. The above are only the main type classifications. In each type, --ball, cylinder roller, tapered roller, spherical roller, thrust, -- many modifications of design are employed. Some of these are the radial (Schulterlager), self-aligning (Pendellager), closed (Rillenlager), angular contact (Schraglager), and long (Langlager). These variations in design afford possibilities of accomodation to special conditions of speeds, loads, thrusts and housings, and result in improved performance. On the other hand, the profusion of types offers obstacles to substitution when bottlenecks develop.

11. In general, bearings with balls as rolling parts are used where highest speeds are required, and bearings with rollers where ability to carry heavy loads is of most importance. Balls can rotate more rapidly than rollers, but the latter, having a much greater surface of contact, can take greater pressures without being affected.

12. The needle bearing is a type of roller bearing used mainly in the tracks of tanks, half-tracks and other vehicles. These could be-- and were--produced by many firms who were not equipped to make anti-friction bearings. Administratively, however, these firms came under the supervision of the Special Ring (Sonderring Waelzlager) as did the makers of flexible joints (Gelenklager) and other simplified bearings and special products.

13. The profusion of types is not due to chance, but the result of the innumerable combinations of load, speed, and thrust to which bearings may be subjected in machine designs. The various types were not equally in demand, as the table clearly shows; ball bearings comprised almost 85 per cent of the total. Numerically less significant types were none the less important, because of their ability to meet specific requirements, and they received special attention from the Germans. Thrust bearings and all types of roller bearings were listed as bottlenecks in December 1943, in a letter from the manager of the Sonderring Waelzlager to the technicians studying replacements of critical anti-friction bearings by plain bearings.

Size of Bearings

14. Bearings vary in size as well as construction. The Germans used standard groupings by outer diameter for major classifications. The following table presents those classifications and a typical distribution for July 1943:

TABLE 5

BEARINGS PRODUCTION BY SIZES
July 1943

SIZE (Outer Diameter) MM	Inches	NAME	OUTPUT In thousands	Per cent
0-21.9	0 - .859	Extra-small	2,908	34.6
22-61.9	.860 2.439	Small	3,418	40.8
62-119.9	2.440 4.719	Medium A	1,539	18.4
120-239.9	4.720 9.449	Medium B	382	4.6
240-and over	9.45and over	Large	13	.2
No size		No size	119	1.4
			8,379	100.0

(Source: Sonderring Waelzlager)

Significance of Size and Type Variation:

15. For the study of the effects of bombing on the German anti-friction industry, the profusion of types and sizes in bearings output is of interest because it imposed a certain inflexibility on production conditions. The machines used for producing bearings of certain specifications were of limited value for the production of bearings of other descriptions. The greatest difficulty, insofar as vulnerability of the industry to attack was concerned, was the size factor.

16. This inflexibility was a handicap to the Germans, since a feature of the conversion of German industry to arms production was the change in the composition of sizes and types of bearings required. Growth in capacity for small and extra-small bearings was particularly needed to meet the demands imposed by the expanded aircraft program. An illustration of the variance of consumption patterns in specific bearings size-ranges is afforded by the following figures, which contrast demand of industries for medium-size bearings with demand for all bearings in 1945 (the only period for which such comparisons are available)

TABLE 6

COMPARATIVE USE PATTERNS FOR MEDIUM BEARINGS AND ALL BEARINGS

	Medium Bearings per cent	All Bearings per cent
Aircraft	14.8	33.2
Tanks	20.6	6.4
Motor Vehicles	22.2	7.7
Weapons & Naval	8.3	5.3

TABLE 6 (Cont'd.)

	Medium Bearings per cent	All Bearings per cent
General Equipment:	11.2	29.5
Electrical	(4.4)	(18.7)
Machinery	(6.7)	(6.1)
Precision Tool & Optical	(.1)	(4.7)
Others	22.9	17.9
	100.0	100.0

(Source: Sonderring Waelzlager)

Some of the significant differences here were the relatively small demand for medium bearings in aircraft (15 per cent) compared with the demand for all bearings (33 per cent). On the other hand, tanks and motor vehicles, which together take up only 14 per cent of all bearings, required 43 per cent of those in the medium size range. The proportion of medium bearings needed by the "Other" industry group was also high (23 per cent). This group, which included such industries as iron and steel producing equipment, rolling stock, and various other metal fabrication industries, was essential in maintaining production in the war economy. However, these industries could, in some cases, be forced to use substitutes for anti-friction bearings if there were not enough for tanks or motor vehicles.

17. Small sizes could be produced at a faster rate than the larger bearings, and it was possible, and it actually happened, that capacity in these size-ranges was built up to a point where it exceeded demand at a time when great difficulty was experienced in other size-ranges. During the course of the raids, output in the extra-small sizes showed an actual over-production while other ranges (medium Ranges A and B) were critically short. The extra capacity could not easily be switched over to the manufacture of other sizes, for conversion of a production line set up for one range could not be accomplished, even for bearings of the same type, without radical alteration of tooling on the machines or substitution of new machines, tooling, gauges, etc. Even if achieved, the result would have represented smaller output than if machines geared to the original size-range had been used.

18. The situation faced by the German anti-friction bearings industry in this regard was expressed succintly in this excerpt from Sonderring Waelzlager statement of 23 December 1944:

"The machine tools are limited in their use to definite size groups. Previous investigations into the installation of plain bearings in place of anti-friction bearings have revealed that the technical

requirements are satisfied mainly in the smaller size-ranges. It is not possible, however, to run freed machine capacity with a maximum outer-diameter of 90 mm to making bearings in Medium B size-range with an outer-diameter between 120 and 240 mm. Also if, for example, through substitution ball bearings in the size-range from 120 to 170 mm are not needed, it is not possible to employ the whole group of machines for bearings of different constructions, such as cylinder roller bearings, tapered bearings, or spherical roller bearings. Only about 60 per cent of the machines of any group are all-purpose machines used in operations that are the same for all constructions. The other 40 per cent are special machines, which can only perform definite operations on a single type of design."

19. The size factor should also be remembered in connection with attempts at substitution of bearings in end-item products. Substitution and redesign were most successful in small bearings, where the production of the anti-friction bearings industry was already adequate, and were negligible in the middle ranges where shortages arose.

Controlled Allocation of Sizes and Types

20. Before the war, the number of sizes and types made by German anti-friction bearings manufacturers was very large. This variety, when uncontrolled, led to numerous disadvantages in both manufacture and design. Ten to twelve thousand different types of bearings had been made by the industry at one or another time--between six and seven thousand by the one firm Kugelfischer. Though these were not all in current production simultaneously, there were continuous repair and replacement requests.

21. An impulse toward standardization was natural and early to develop. Its minimum goal was standardization of bore and outer dimensions, in order to enable replacement without redesign of the housing. Early efforts dated back to World War I, and had progressed steadily since that time. In 1943, a Standardization Committee led by Dr. Wilhelm Jurgensmeyer of the VKF firm arrived at a grouping based on 2,800 types. Under the controls which were then in force through the Sonderring Waelzlager, an agency was set up in that organization to assure that bearings users followed this simplified classification wherever possible in specifying their requirements.

22. Accompanying the standardization program in its later stages was planned distribution of types among the bearings firms ("Typenaufteilung der Genormten Waelzlager,") also prepared under Jurgensmeyer's supervision. The purpose was to increase the efficiency of the industry as a whole, and of individual firms, by allocating to each of the six largest firms the bearings types it was best qualified to manufacture. These firms could produce only bearings allocated to them. Each was to produce certain types up to capacity; other types were to be produced only when a primary manufacturer had insufficient capacity to meet

total demand. The scheme operated to prevent duplication, despite occasional commercial discrimination in the allocations or failures to gauge capacity correctly. With the extension of full powers over control of orders to the Sonderring Waelzlager in October, 1943, however, the allocation program lost its separate importance. Its value had always been indirect in comparison with the expansion plans which it complemented; these will be described more fully in a separate section.

Manufacturing Techniques

23. The manufacturing process for anti-friction bearings mirrors the complexity and precision of the product. The operations are numerous and precise, and are carried out separately for rings, retainers, and rolling parts. The production of retainers is the simplest. This component is made in a stamping operation on standard single-action stamping presses. Major attention in the production process is devoted to the manufacture of the rings and rolling parts, both of which require a production time-cycle of considerable length. The cycle is about three months under ordinary conditions, though it may run to twice that period. About one month is spent in preliminary machining and turning ("soft operations"),, another month and a half in heat-treatment and grinding ("hard operations"), and one-half month in assembly. The raw material for manufacture is steel of high quality chrome alloy; it comes in cold-drawn wire for balls and in tubes (Rohre), bars, or forgings (Knuppel) for rings. The chief manufacturing supplies are grinding wheels and abrasives, and petroleum products for quenching, lubrication, rust-prevention and packing.

24. The manufacture of anti-friction bearings requires a large number of various types of machine tools, (whose number in Germany in July 1943, on the eve of the attacks, was estimated at 13,000.) The machine tools used in the bearings industry can be placed roughly in two categories; those made especially for the industry according to specification, and standard machine tools adapted to the bearings industry by special tooling. Specially designed tools were build mainly by VKF at Stuttgart and a shop in Frankenthal, or obtained from Sweden. Special tooling of standard machines, as well as machine manufacture, was carried out generally in the plants' own tool shops. Specially designed machines were used mainly in the production of balls; among the standard machines were multiple spindle automatics, centerless and cylindrical grinders, internal grinding machines, and standard turret lathes. In addition to machines, considerable equipment in the form of cranes, furnaces, boilers, compressors, pipes, pumps and measuring devices were essential to the production process.

25. It is characteristic of the manufacturing process that the various components were made separately and only flowed together at the assembly point. This independence of ball- roller-, ring-, and cage-(retainer) manufacture enabled relatively efficient production under

conditions of decentralized manufacture, since various departments could be dispersed as units without great duplication of machines or installations.

26. Modern bearings plants in Germany were usually single-story sheds to permit maximum and uniform light, but many of the older buildings in Schweinfurt were multi-story. Bearings plants required no unusual types of construction. Any machine shop was readily convertible to bearings manufacture with such minor additions as trenches to carry off cooling fluid from grinding, or ventilating apparatus to draw off smoke and fumes from quenching. The only conditions to be met for putting factories underground, a measure adopted during the raid period, were the need for adequate lighting for the machine tenders and inspectors, and for air-conditioning to prevent rust of machined parts.

Labor

27. The working force of the anti-friction bearings industry on the eve of the attacks is described in the following table, showing skill, sex and nationality characteristics.

TABLE 7

WORKERS IN THE GERMAN ANTI-FRICTION BEARINGS INDUSTRY
July 1943

(a) By Skill, Sex.

	Number			Per cent of workers according to skill	Per cent Distribution by Sex.		
	Total	Male	Female		Total	Male	Female
Tech-Comm.	4,233	2,107	2,126	12.6	100.0	49.8	50.2
Skilled	3,030	3,030	-	9.0	100.0	100.0	-
Semi-Skilled	18,383	10,745	7,638	54.8	100.0	58.5	41.5
Unskilled	7,914	4,828	3,086	23.6	100.0	61.0	39.0
Total	33,560	20,710	12,850	100.0	100.0	61.7	38.3

(b) By Nationality

	Number			Per cent		
	Total	Male	Female	Total	Male	Female
German	22,801	14,026	8,775	67.9	67.7	68.3
Foreign	10,759	6,684	4,075	32.1	32.3	31.7
Total	33,560	20,710	12,850	100.0	100.0	100.0

(Source: Records Sonderring Waelzlager)

28. About 55 per cent of the labor force was in the semi-skilled classification. In this category, as well as in the unskilled group, an ample supply of labor was available, due to the regular contingents of foreign civilian workers and prisoners of war placed at the disposal of the industry, and because of the availability of Germans migrating from farms in the vicinity of the plants. The increase in the numbers of the latter group, in fact, was maintained at a rate which caused overcrowding of Schweinfurt and was one of the factors causing some decentralization or dispersal of plant facilities before the attacks took place.

29. The production of anti-friction bearings also required a large staff of technically trained personnel, supervisory and skilled workers. The supply of such workers was adequate before the raids began, but became short when plants were dispersed during the raid period. As a measure for meeting the need for skilled workers, apprenticeship programs were carried out in most plants.

30. About a third of the workers were foreign, almost all in the unskilled and semi-skilled classifications. Women formed a large minority (38-39 per cent) of the working force, among both the foreign and German groups. Plant records indicated that foreign workers, while not so efficient as Germans, were improving steadily; by 1943 Russian workers were estimated by the Sonderring labor specialists to be only 20 per cent less efficient than Germans.

31. In general, the industry operated on a two-shift system of 60 hours per week per shift. The Sonderring sought to introduce a 72 hour week, but this goal was achieved only in a few plants and departments. Actual hours varied among plants and within plants. Split shifts, half-day workers and overlapping shifts were utilized in several factories, as indicated by the summaries of plant reports presented later. For example, male employees of the Muller firm, at Nurnberg, worked 12 hours per day, seven days per week, while women worked 12 hours for six days on machines, and a 58-hour week on inspection. In another case, the employees of the Jaeger plant worked 55-60 hours, on the average, with Saturday afternoons and Sundays off.

The Anatomy of the Industry; Geographic and Economic Factors

Geographic Concentration

32. In the middle of 1943, on the eve of the combined bomber offensive upon the German anti-friction bearings industry, the main producers in Germany were concentrated in four places; - Schweinfurt, Cannstatt, Berlin, and Steyr, Austria. By far the most important of these was Schweinfurt, a city of 60,000 population located in Bavaria on the Main River. The following figures show the relative importance of production in these centers, in terms both of the number of ball and roller bearings produced, and of value of product in July 1943:

TABLE 8

GEOGRAPHICAL DISTRIBUTION OF OUTPUT

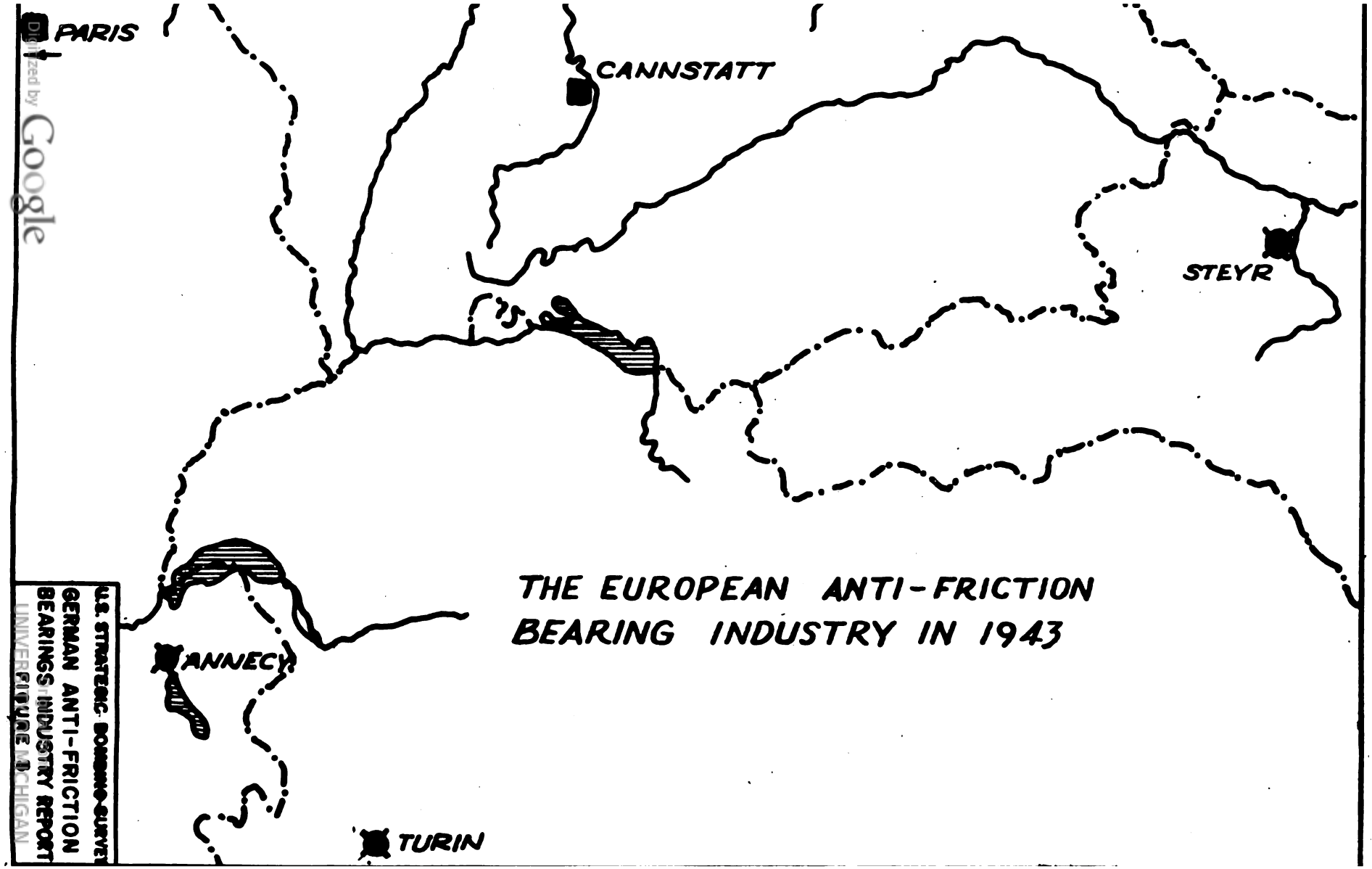
Places	Plants	No of Bearings	Per cent	Value in Thous. RM	Per cent
Schweinfurt	3	3,771	45.0	12,250	52.2
Cannstatt/Stuttgart	1	1,533	18.3	1,921	8.2
Berlin	2	1,094	13.0	2,049	8.7
Steyr, Austria	1	854	10.2	2,734	11.7
Other Plants in Ger.	35	1,127	13.5	4,499	19.2
Total	42	8,379	100.0	23,453	100.0

33. The Schweinfurt plants included the two works of the Vereinigte Kugellager Fabrik (VKF) and the Kugelfischer AG (FAG) factory. Two other plants of minor importance in the anti-friction bearing industry, Deutsche Star Kugelhalter and Fichtel und Sachs, were also located in Schweinfurt. The former made metal retainers, a component in bearings production, while the latter, primarily a producer of bicycle brakes, clutches, and other motor components, manufactured some needle bearings. Data on these plants is not included above.

34. Of the centers outside of Schweinfurt, the Norma works of VKF was located in Stuttgart, while Berlin was the home of two plants, the Erkner factory of VKF and the Norddeutsche Kugellager Fabrik (NDK) or the Kugelfischer firm. The plant in Steyr, Austria was that of Steyr-Daimler-Puch. (See Map - The European Anti-Friction Bearings Industry, Figure 3.)

35. The remaining German plants, while accounting for only a small part of the total number of bearings produced, included several which were important for the specialized character of their product. The nature of the output of all principal German plants will be described later.

36. Although the German war economy had to depend on plants within the territories of the Reich for the bulk of its bearings needs, Germany's position as dominant power on the continent of Europe brought additional sources of bearings under her control, in countries occupied by or co-operating with her. Data on the number of ball and roller bearings produced in these plants, as well as detailed production figures on plants within the Reich, are presented in Table 9. In the expanded total of bearings available to Germany in July 1943, German production amounted to 77 per cent. Of the remainder, the CAM plants at Paris, and the SRO plant at Annecy, France accounted for an additional eight per cent, and RIV at Turin for two to three per cent. However, the greatest single source of ball and roller bearings outside of Germany



was the SKF works at Goteborg, which contributed nearly 12 per cent of the total available for German needs.

Economic and Industrial Characteristics

37. The bulk of the production of German anti-friction bearings was in the hands of two firms -- the Vereinigte Kugellager Fabrik AG (VKF), which is a subsidiary of the international Svenska Kugellager Fabrik (SKF), and Kugelfischer AG (FAG), an independent German enterprise. As Table 9 shows, the two firms controlled 78 per cent of production in Germany in terms of number of bearings, and 75 per cent in terms of value. The balance of German production was divided among relatively small independent producers.

38. The VKF combine came into existence in 1929, when the Swedish SKF corporation bought the stocks and properties of several leading German producers. In doing this, SKF was continueing a course it had followed elsewhere, -- notably in the United States (SKF), England (Skefco), and France (CAM)-- of setting up new facilities and buying up those existing, in the process of forming an international combination with the leading position in the world bearings market. The principal German producers bought out were Fries and Hopflinger and the ball-bearings departments of Fichtel and Sachs, both located in Schweinfurt, which, together with additional construction became VKF Works I and II, and the Berlin-Karlsruhe Industrie Werke, which was succeeded by the VKF Erkner plant. SKF already owned the Norma plant in Stuttgart, and the SKF plant at Purstein, Czechoslovakia, which after 1938 was adopted by the German concern. A few smaller plants, bought at the same time, were dismantled, and the machines removed to the Schweinfurt, Stuttgart and Berlin works.

a. Works I and II, located at Schweinfurt, were the main center of the VKF combine. These plants manufactured ball and roller bearings, chiefly in the small and medium ranges, of standard and special types. Works II made balls in sufficient quantities to supply other VKF plants, and also to sell to independent producers. A large machine tool shop was located in a part of the plant; in addition to supplying the needs of the VKF Schweinfurt plants, tools were made for other VKF and independent plants. Total employment at the VKF Schweinfurt works was 7,844 in mid-1943, and production (in value) was 25 per cent of the German total.

b. The plant at Bad Cannstatt/Stuttgart specialized in small-size ball and roller bearings, such as magneto type bearings and other special types. Special bearings were also made in large-sizes. A large machine shop made textile spindles with needls roller assemblies as well as machine tools for bearings production. Rollers were produced in large enough quantities to supply the needs of other plants. This plant employed 3,714 workers and produced eight per cent (by value) of the German total.

c. The Berlin/Erkner factory produced medium and large sizes of ball and roller bearings, using balls obtained from the Schweinfurt plant. Total employment was 1,826 workers and the value of the output represented seven per cent of the whole German anti-friction bearing industry.

d. The SKF Puerstein works in Czechoslovakia specialized in small size bearings, employing 269 persons and accounting for less than one per cent of the total.

39. The only important competitor of the VKF combine, Kugelfischer A.G., was a family enterprise dating back to the 19th century. Bought by the Schafer family in 1909, it underwent a program of continuous expansion which brought it to a position of practical equality in importance with VKF in 1943, and eventually to the point where it overshadowed its rival at the close of the war. The formation of the VKF concern in 1939 inaugurated a period of fierce competition. From that year until 1933, when Hitler came to power, the Fischer firm was sustained chiefly by its export business, particularly with Russia. With the advent of the Nazi regime, emphasis on nationalism came to the aid of the firm, which exploited its position as the only producer of importance with a completely German management. With the outbreak of war and the resulting great increase in demand, the need for sharp competition lessened, or rather was submerged in the desirability for cooperation in the industry to meet its tasks in the armament program.

a. The FAG plant at Schweinfurt, which was the principal Fischer plant, manufactured a complete line of ball and roller bearings of standard and special types. It turned out balls for the other FAG plants and for sale to independent producers, and a large proportion of the FAG needs for grinding-wheels. This plant employed 9,770 workers in July, 1943, and produced 27 per cent of the total value of the German industry.

b. The factory at Elberfeld/Wupperthal, in the Rhineland, specialized in ball and roller bearings of large sizes, such as are used in railroad and marine equipment. This factory, though generally known to be a Fischer subsidiary, did business under the name of G. & J. Jaeger. Balls were obtained from Schweinfurt. The factory also produced considerable quantities of needle bearings. Employment was 1,764, and output represented five per cent of the German total.

c. The Nord-Deutsche Kuggellager Fabrik (NDK), at Berlin, was another Fischer subsidiary. About half of the production of this plant consisted of needle bearings in 1943, and later during the war the entire factory change-over to the manufacture of these special bearings. Before the raids, smaller sizes of ball and roller bearings made up the remainder of its product. Balls were obtained from Schweinfurt. The employment of this plant was 560, and value produced was 1.5 per cent of the total German output of anti-friction bearings.

TABLE 9

NUMBER OF VALUE OF BALL AND ROLLER BEARINGS PRODUCED IN GERMAN AND AXIS CONTROLLED PLANTS, PRE-RAID 1943.

Firms and Plants	Bearings Produced- (All Axis plants)- July 1943			Value of Production (Reich Plants only) (Mo Av 2d Qtr' 43)		Pre-Raid Intell Estimates	
	No in Thousands	Per cent All Plants	Per cent Reich Only	(Thousands RM)	Per cent	Per cent all Plants	Per cent Reich Only
VKF-Schweinfurt, (2 Plants)	1,767	16.3	21.1	5,859	25.0	23.0	27.9
Stuttgart/Cannstatt	1,533	14.1	18.3	1,921	8.2	6.5	7.9
Berlin/Erkner	1,026	9.4	12.2	1,692	7.2	5.5	6.7
Fuerstein	59	.5	.7	86	.4	1.0	1.2
Total	4,385	40.3	52.3	9,558	40.8	36.0	43.7
FAG Schweinfurt	2,004	18.3	23.9	6,391	27.3	25.0	30.3
Elberfeld - (Jaeger)	56	.5	.6	1,181	5.0	2.3	2.7
Berlin (DKF)	64	.7	.8	357	1.5	1.0	1.2
Total	2,124	19.5	25.3	7,929	33.8	28.3	[illegible]
Steyr-Steyr, Austria	854	7.8	10.2	2,734	11.7	8.0	9.7
DKF-Leipzig	100	.9	1.2	1,396	5.9	2.3	2.7
Muller-Nurnberg	402	3.6	4.9	363	1.5	2.2	2.7
Kling-Wetzlar	68	.6	.8	279	1.2	1.0	1.2
All other Reich	446	4.0	5.3	1,194	5.1	3.7	5.8
Total	8,379	76.7	100.0	23,453	100.0	81.5	100.0
CAM Paris	750	6.8				6.5	
SRO Annecy	120	1.1				1.5	
All other France	100 1/	.9				1.0	
Total France	970	8.8				9.0	
FIV Turin	250 1/	2.3				5.5	
All other Italy	75 1/	.7				1.0	
Total Italy	325 1/	3.0				6.5	
Swedish Imports (SKF Goteborg)	1,260	11.5		(3,024)		8.0	
GRAND TOTAL	10,934	100.0				105.0 2/	

Source: Records of the Sonderring Waelzlager, Fachgruppe Triebwerke and Waelzlager, VKF Schweinfurt, and releases of the Ministry of Economic Warfare.

1/ Estimated

2/ Does not total to 100 per cent because of roughness of individual estimates.

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40. The third most important firm in the German anti-friction bearings industry was the Steyr-Daimler-Puch Waelzlagerwerk, a part of the Steyr-Daimler-Puch AG combine, manufacturers of motor vehicles, aircraft and weapons. The bearings firm (hereafter referred to as Steyr) was founded by the parent organization to furnish the needs of the main works. Eighty per cent of the stocks of the latter was owned by the Austrian state and, after the Anschluss of 1938, passed into the hands of the Hermann Goering Works. The latter immediately announced plans for the building of a new plant, construction of which was completed in 1941. This permitted Steyr to make a great increase in the amount of its product available for sale to consumers in general. In conjunction with the Hermann Goering concern, the Deutsche Industrie Bank had a financial interest in Steyr.

41. The Steyr plant, located in Steyr, Austria, made a complete line of standard catalog ball and roller bearings, as well as special types for aircraft such as propeller thrust bearings, of which it was the principal producer. Steyr was not equipped for ball production in 1943, procuring balls and some of its rollers from outside, but was developing facilities for producing more of these components. By April 1944, the plant became able to produce the greater part of their needs. Steyr employed 4,474 workers in July 1943, and was responsible for 12 per cent of the industry's output of bearings.

42. Deutsche Kugellager Fabrik (DKF) was an independent small producer with two plants in different sections of Leipzig. DKF concentrated on ball and roller bearings in the middle size ranges. Much of its production went into special type bearings, such as variable pitch propeller bearings and special needle bearings. DKF bought its balls from other producers. Employment of this firm was 1,177 and output amounted to six per cent of the total industry.

43. Two other firms complete the description of the six producers whose plants accounted for 95 per cent of German production of anti-friction bearings. Kugellager Fabrik Georg Muller, of Nurnberg, specialized in the production of high-precision small and smallest-size bearings used chiefly for optical and precision instruments. It also produced specials in a few other sizes, and a small number of grinding spindles. Balls were produced in a subsidiary plant at Ansbach. Muller employed 978 workers in mid-1943 and accounted for 1.5 per cent of total production. Roberg Kling, Wetzlar, specialized in small and medium ball and roller bearings, although capable of producing larger sizes as well. Balls were obtained from outside sources. Kling employed 600 workers and produced 1.2 per cent of the industry's output.

44. The specialization in sizes and types of bearings produced by individual plants, as described in the foregoing paragraphs, was partially the result of market forces tending to promote division of effort into convenient avenues of trade for each firm. An equally important

factor has been referred to earlier the directives of the Sonderring Swelzlager, which sought to increase efficiency in the industry by allocating specific size ranges and types to firms and plants. This tendency toward avoidance of duplicating capacity in plants was never carried far enough to make the industry more vulnerable to strategic bombing attack by complete elimation of duplicate facilities for each type of production. The strong competitive feeling in the industry was partly responsibe for this caution, along with an early recognition by the officials of the military danger of excessive concentration.

45. In addition to the six major firms, some 20 to 25 other producers, employing from 25 to 500 workers each, had a share in the industry. The more important of these made components of bearings for sale to the principal manufacturers. The following should be mentioned: Deutsche Star Kugelhalter, Schweinfurt, manufacturer of metal retainers whose production of 2,500,000 retainers in July 1943 was the approximate equal of Kugelfischer's; and three manufacturers of balls only; Gebauer and Moller, Fulda; Gebruder Heller, Marienta; and Schulte, Tenta.

46. The production of needle bearings -- 1.1 million monthly in mid-1943 -- was widely spread over a number of producers. Manufacturers of needle bearings included not only the Berlin and Elberfeld plants of FAG, and the DKF plant at Leipzig, but also many firms which manufactured bearings as a sideline, such as Fichtel and Sachs of Schweinfurt (producing some 223,000 in July 1943,) Durkopp Werke of Bielefeld, and Schumag. Geographical concentration of production of these bearings was not pronounced.

47. Among foreign sources of anti-friction bearings available to Germany, the imports from the SKF plant at Goteborg, Sweden, stand out. While it is true that the French and Italian producers, principally CAM, Paris, SRO, Annecy, and RIV, Turin, together produced 11 per cent of all bearings available to Germany (Table 9), much of their production was needed as components in the production of armaments or by equipment plants in those countries, and so could not enter directly into the main German armament program. In addition, a considerable part of their product had to be used in the production and repair of essential equipment in the domestic economies of France and Italy. These factors were not present in the case of imports from Sweden.

48. Bearings delivered from the Goteborg plant in July 1943 comprised 12 per cent by value of the total produced in Europe available to Germany. They amounted to 1.3 million bearings, which because of their nature -- the Germans generally ordered from the Swedes those sizes and types which were most difficult to supply at home -- made the Swedish source fully as important as any German plant, save the great FAG or VKF plants at Schweinfurt.

Figure 4 - Aerial photograph of Schweinfurt.

THE GERMAN ANTI-FRICTION BEARINGS INDUSTRY

The Enemy's Safeguards

49. The previous sections have indicated some of the characteristics of the German anti-friction industry which made it vulnerable to attack. To summarize, the anti-friction bearings industry had 1) a high concentration of capacity in individual plants, 2) an essential share in maintaining production in most armaments industries.

50. It is logical to enumerate some of the factors which on the eve of the attacks served as the industry's safeguards against damaging consequences from air offensive.

"Pipeline" from Bearings Plant to Battlefield

51. As a metal working industry manufacturing parts, the bearings industry stands between the extraction industries and the military end-item producers. Its products do not appear immediately in the front lines; instead, there is a long "pipeline" or period of time between the completion of the bearing and its actual functioning in the equipment of which it is a part. The length of this period depends upon the final use and the stage of assembly at which it is required, and varies from several months, in the case of ship-building and machine-tool construction, to a matter of weeks for mass-produced items such as motors, tanks and trucks.

Level of Efficiency and Design

52. One of the factors providing a considerable but immeasurable amount of cushion against serious production loss due to air attack was the differing level of productive efficiency among the several producing firms. While the VKF firms were, in general, producing with up-to-date methods, the Kugelfischer plants were in many cases producing under relatively inefficient conditions. Moreover, according to German as well as American expert opinion, few plants in the entire German industry came up to the levels in American and British plants with respect to the organization of production or processes used, and German production men were aware of this. The significance lies in the fact that organization could be tightened when need came upon the industry, even though inefficiency of technique was not, of course, planned as a safeguard.

53. At the same time German equipment was unduly lavish in the amount of anti-friction bearings incorporated in its design. This was due partly to convential German engineering practice and partly to the promotional efforts of the German bearings industry, which tried to design bearings to fit all types of conceivable applications, many of which could have been served well enough with plain bearings or bushings. There was considerable room for redesign and substitution if bearings supply ran short.

Sonderring Waelzlager

54. The existence of the Sonderring Waelzlager (Special Ring for Anti-Friction Bearings) after March 1942, was another safeguard of the industry. As related in Chapter 7 of this report, this body was staffed with able men, experts in the application, production, and distribution of bearings. It was organizing efforts to strengthen the industry before the air attacks, and was ready with a program of essential counter-measures when the air offensive came.

55. On the basis of a study of orders and aircraft programming in August 1942, the Sonderring reported that the production of smallest bearings for the Luftwaffe would have to increase fourfold. An expansion of small bearings capacity was carried out which (combined with a lessoned demand when bombers became less important) kept that size range from ever becoming a difficulty.

56. As other special programs were initiated by the Wehrmacht--the "Adolf Hitler Program" for tanks, for example -- the bearings industry attempted to expand and readjust itself to their demands. Piecemeal measures produced conflict, however, and in early 1943 the Sonderring undertook a survey of prospective demands from its customers. The results, showing a prospective requirement of twice the existing capacity, furnished the basis for the first comprehensive plan for the industry, Called the "Aufstockung" (building-up) or "Verdoppelung" (Doubling) program; it aimed at a doubling of output in 1944. The resources of the industry (mainly the six major firms) were studied, and plans for input of additional labor and machines were worked out in great detail. The machine program included 3,630 new machines from Germany and Sweden, most of which were ordered by the time of the August attack on Schweinfurt with delivery dates in late 1943 or the first half of 1944. The production goal was set at 14,500,000 bearings monthly, actually not quite double the average monthly production of eight million bearings in the spring quarter of 1943.

57. Complementing the planned expansion was a program of encouragement of dispersal. The major firms had begun dispersal in 1942, mainly because of the crowding of Schweinfurt. In May 1943, the Reich Air Ministry initiated a unified program, the first undertaken with protection against air attack as the aim, supervised in conjunction with the Speer Ministry by the Sonderring Waelzlager. The plan was simple: no more than 39 per cent of the German production of any type and size (for example, small ball bearings, or medium tapered bearings) was to be located in one plant. The dispersal was geared into the expansion program so that current production at original plants would not be cut down.

58. Space in textile factories, stone works, and small machine shops was obtained through the Armaments Inspections Commands. By the time of the industry-wide survey taken in October 1943, 32 projects

were underway, the majority under construction, but six actually producing. Of these 32, 20 were Kugelfischer, and 12 VKF dispersals. About 113,500 square meters of floor space were being converted into dispersal factories, with 13,100 more acquired for further expansion. These 127,000 square meters compare with a basic 500,000 square meters for the industry before dispersal. In virtually all cases, dispersal was by departments, with manufacture of single components, or final operations and assembly of one size range, moved from the main plants to subsidiary works.

Military and Physical Defenses

59. Aside from this early dispersal program, which was part of a general effort of the Air Ministry to disperse armament production plants, there were few efforts to deploy or protect the facilities of the industry physically. Dispersal progress was slow and half-hearted prior to the air attacks, and expansion of plant within the original works areas at Schweinfurt and Steyr went on as late as 1943. Moreover, in the construction of a large building in the Kugelfischer plant at Schweinfurt in 1943, no effort was made to reinforce walls or roofs to withstand air attacks, nor were bunkers or shelters prepared before the first raid. This was in spite of the fact that many Germans expected reprisals on Schweinfurt for several attacks on British anti-friction bearings plants.

60. On the other hand, the military protection of Schweinfurt on the eve of the attacks was formidable. Aside from the fact that the Luftwaffe had an imposing number of fighter planes to engage bombers at the approaches to the Reich, Schweinfurt had 12 flak stations. Such an array, mounting 76 88-mm guns, undoubtedly reflected a recognition in important quarters that Schweinfurt, the key bearings center, was likely to be selected for air attacks and had to be staunchly defended.

Position of Bearings Industry in the Economy

61. In spite of the key importance of anti-friction bearings as a component of all types of equipment essential to modern warfare, the industry itself is relatively small. A few comparisons of basic measures of industry size bring this out. Total employment in bearings manufacture was 35,000 in 1943, or .3 per cent of the total of 12 million workers in all manufacturing in Germany. Machine tools, the most important item of capital equipment in the bearings industry, tools, numbered 13,000 at that time, less than one per cent of a total of two million machine tools in use in all Germany or about the equivalent of the monthly rate of construction. The ratio of workers per machine, 2.2, did not differ significantly from the national average of 2.35 for the metal working industries.

62. Finally, the value of the yearly product in 1943, -- RM 280 million - is .4 per cent of the value of national product for that year,

estimated at about RM 70 billion by the Plannungsamt. The importance of the industry, which cannot be shown by its size, or the value of the product, must be judged instead from the way in which its use cuts across the whole machine economy, from the indispensability of the bearings in armaments, and from the contributions they make to performance.

CHAPTER THREE THE COMBINED BOMBER OFFENSIVE

A. THE ALLIES ATTACK: THE EXECUTION OF THE OFFENSIVE

The Schweinfurt Raids *

1. The initial blow was struck on 17 August 1943 by a force of 183 Flying Fortresses. Only in June with the arrival of "Tokyo Tanks" had so deep a penetration, 460 miles from English Bases, become possible. The bombers outranged their escort, which was left at the German-Belgian border. Unprotected, they were subject to fierce and unremitted attack and lost 36 planes, a fifth of the attacking force. A night raid by the RAF had been planned to supplement the daylight attack. Bad weather forced postponement of the American raid from early in August until the 17th, however, and by that time the full moon made the RAF attack impractical.

2. A bomb load of 434.8 tons was dropped on Schweinfurt; 80 high explosive hits were identified by the plant officials in the FAG and VKF plants. So far as actual productive processes were concerned, damage to the VKF plants was unimportant; the most severe effects were felt at Kugelfischer, where 663 machines were destroyed or damaged. Most serious was the extensive damage to the ball department, whose operations at that time accounted for the bulk of total FAG ball output. The seriousness of the damage in this department is shown by the level of its output, which dropped from 140 tons in July to 69 in August and 50 in September. An upturn did not come until November.

3. Other processes in FAG were hit as well -- the solid cage department, the roller department, and the large bearing departments in particular. This last-mentioned loss stimulated the development of a dispersal plant at Kirchheim, to which all such production was rapidly moved.

4. On 14 October 1943 came the most important raid on Schweinfurt, the raid which caused the most damage and the greatest interference with production. It led directly to the appointment of Mr. Kessler as General Kommissar for the Bearings Industry, as described elsewhere in

* To illustrate the impact of the combined bomber offensive, a summary account of the Schweinfurt raids follows. The full story is contained in the Reference Notes, summed up in Exhibit B. Physical Damage Report Number 18 is also pertinent. Other attack and damage data are discussed in Chapter Four and the reference notes thereto. The Schweinfurt story will suffice here to make the later generalizations on attack and damage vivid and meaningful. The photographs and plans in Exhibit A, compiled by a Physical Damage expert, illustrate the narrative.

this report. A force of 228 heavy bombers from the 1st and 3rd Bombardment Divisions of the Eighth AF made the attack; they were to have been joined by B-24s from the 2nd Division, but these, failing to arrive at the rendezvous, were switched to a diversionary target elsewhere. Then ensued one of the greatest battles of Eighth Air Force history. Wave after wave of German fighters attacked from the time the bombers crossed the German frontier. There were 291 encounters in all. Flak was intense over the target, but good visibility enabled the Fortresses to make an accurate bomb run.

5. Damage was heavy. Best results were obtained from the 24 HE and seven IB bombs which hit VKF Works 11. As though designed to complement the effects of the August bombing on FAG, here again it was the ball-producing plant which suffered most heavily. The loss of ball output affected operations not only here, but in other plants as well, since Works 11 made all the balls used by the entire VKF firm, including the Erkner and Cannstatt complexes, and sold balls to outside firms. In other parts of Work 11, 23 machines were destroyed and 54 damaged, mostly in the cage-making department and tool shop.

6. Thirty-eight HE bombs hit various parts of VKF's Works 1, but the six story building housing the bulk of its productive operations was scarcely damaged. Sixteen machines were destroyed and 15 damaged, mostly in the department producing extra small bearings; apart from this single instance, the plant resumed operations as soon as power had been restored and a little plaster had been dusted off the machines.

7. In this same raid, FAG lost 374 machines - 84 being totally destroyed and 290 damaged. Chiefly affected was production of large bearings and of rollers and cages; as a result this section was subsequently dispersed to a large extent or moved into basements. Bombs also fell on the departments housing assembly and grinding of medium bearings, on the tool shop, and on the forge. All in all, damage, though substantial, was considerably less in this raid than in the raid of 17 August.

8. Despite the crippling of some departments and sections, production on the whole received no more than a temporary setback. Overall machine damage for the two VKF plants and the FAG plant amounted to only 10 per cent; 3.5 per cent destroyed and 6.5 per cent damaged. Total direct cost of this raid to the Germans, estimated at 18 million Reichsmarks, was twice that of its nearest contender.

9. This degree of damage, however, was achieved to a heavy cost to the Eight AF. The force which returned to its English bases was a sadly depleted one. Sixty-two of its planes had been lost, 17 had suffered major damage and another 121 had received minor and easily repairable damage. No air force can continue to absorb such losses.

Accordingly, the Eighth AF had to confine its future operations to the areas where fighter protection was available. This meant that until the arrival of sufficient long-range P-51s, operations deep into Germany were impossible. In one raid, the Eighth Air Force had temporarily lost its air superiority over German targets.

10. The aerial attack in Schweinfurt now entered a four-months' lull. P-51s for long-range fighter escort became available in December, but weather difficulties and other bombing commitments prevented a resumption of the campaign until late in February 1944. This time, the previously sought day-night coordination was achieved through a combination of two night raids by the RAF, and one daylight American raid, during 24/25 February. Almost three thousand tons of bombs cascaded from the skies, three thousand tons which found awaiting them a considerably diminished production center. Since the October raid, VKF, for example, had moved 549 machines to locations in dispersal plants. Of its entire stock of machines, the Schweinfurt complex now had only 73 per cent in the plants in that city. Kugelfischer's dispersal had progressed to an even further extent; only about half the machines were still in the VKF and FAG plants; Schweinfurt was only about 60 per cent the target it had been in August 1943.

11. With these three raids coming in such rapid succession, it is difficult to isolate the effects of each individual attack; accordingly, this discussion will lump the three together. Over-all damage was computed at 14 million Reichsmarks, a figure lower than that for the single attack of 14 October 1943. Of the reduced number of machines now set up in the target, 16 per cent were affected, 8.5 per cent being destroyed and 7.5 damaged.

12. Once again VKF felt this raid chiefly in the departments performing "soft" turning and grinding operations on rings. The ball department, already nearly half dispersed, lost another 39 (10 per cent) of the machines remaining in Schweinfurt. Other bombs hit and destroyed the forge.

13. Works 1 was hit 28 times, but once again escaped with no greater damage than the destruction of 16 assembly machines. Hard ring operations, which formed the most important part of this plant's productive activities, were still largely unaffected, as no raid had yet brought any damage here. Many of the bombs fell in previously destroyed sections now being rebuilt, for example the shipping department. In spite of the fact that most productive facilities remained unscathed, however, officials were sufficiently worried to decide to disperse part of assembly to Grettstadt.

14. There followed a series of largely ineffective raids, beginning with that of 24 March when 60 Eighth AF bombers missed the

bearings factories altogether. A 104 ton raid by RAF bombers on the night of 30/31 March caused some building damage at VKF, but left machines and productive facilities untouched.

15. Next came the daylight raid of 13 April 1944, which cost FAG five million Reichsmarks in damage and construction costs. Hardest hit was the department producing medium bearings, where eleven HE and eight IB bombs caused enough destruction to bring production to a virtual halt for the rest of the month. Output in both Schweinfurt and dispersal plants, which in March had reached the figure of 372 thousand units, fell to 132 thousand in April. Some small measure of recovery had been attained by May, when output stood at 169 thousand, but the Schweinfurt plant's share in these figures shows an even more marked decline; 327 thousand in March, 103 in April and 38 in May. Less heavily hit were the forge, annealing ovens, and small-bearing department. Altogether, 67 machines were destroyed and 503 damaged, thus putting out of operation 23 per cent of previously used machines.

16. In this same raid, VKF suffered relatively little damage from the five HE and eight IB bombs which hit its two plants. The incendiaries were soon brought under control, and productive facilities were scarcely damaged. Only eleven machines suffered any damage at all. Total cost of the raid to VKF amounted to .3 million Reichsmarks.

17. The three months' lull which followed was broken in the latter part of July, when two daylight raids by bombers of the Eighth AF caused an estimated eight million Reichsmarks' damage to the bearings plants.

18. Though more tons of bombs were dropped in the raid of 19 July, more serious damage resulted from the second raid, that of 21 July. In VKF, for example, the damage evaluation was three million Reichsmarks for the raid of the 19th, but the damage inflicted caused no interruption to production. Works 11 once more received the greater portion of the damage, mostly on the 21st. Machines were not greatly affected, most of the destruction being to buildings. The first raid saw three machines destroyed, six damaged; the second and more successful resulted in the destruction of 11 and damage to 62. The largest part of these were in the much beleaguered ball plant, which also suffered heavy building damage.

19. The great disparity between the strength of the attack and the results is at once apparent. Total production in the Schweinfurt complex dropped from 1.6 millions of bearings in June to 1.3 in August, rising to 1.5 again in September. Basically, the reason for this slight drop lay in the fact that by this time 42 per cent of the machines had been sent to dispersal plants. The bombers raiding the Schweinfurt

plant had only 58 per cent of the original target to attack, and important sections of this - e.g., the ball department - had been protected by blast walls. Only five per cent of the machines remaining there were destroyed or damaged.

20. Heavier damage in FAG added up to a total of 4.9 million Reichsmarks. Bombs destroyed 55 machines and damaged 11 others in scattered departments, such as those making cages damaged as well. Damage had fairly little effect on total production, however. Total FAG output of bearings, which stood at 1,402 thousand in June, was 1,491 thousand in July and fell only to 1,459 thousand in August.

21. The heaviest single American raid was that of 9 October 1944, when 820 tons of bombs, mostly HE, were dropped on Schweinfurt, whose importance had declined still further. In the case of VKF, for example, only 46 per cent of the Schweinfurt complex's machines were located in the two main works in this city, while FAG had dispersed to an even greater extent.

22. FAG was not affected by this October raid. Neither was VKF's Works 1: the six story building which housed most of its productive facilities had managed to escape serious damage in all of the air raids. VKF Works 11 lost 44 machines destroyed, and 76 damaged, most of these being located in the machine and tool rooms, which thus lost 31 per cent of its machines. An estimate of cost of the raid to VKF places this figure at 3.2 million Reichsmarks.

23. October 9 virtually marked the end of the strategic bombing attacks on Schweinfurt. A subsequent attack of 23 February 1945, directed against marshalling yards, caused no damage to the plants. Immediately before the fall of the city to ground troops, a tactical raid on 10 April 1945 caused some damage, but at this date the effect on production and operations was of no account.

Summary of Attack Data (See Exhibit "B")

24. The attack on the bearings industry was adapted to the structure as described in the preceding chapter. As Figure 5 ("Weight of Bombs to Percentage of Importance") shows, the greatest weight of bombs fell on Schweinfurt, the heart of the industry. The raids covered the whole industry, however: the plants directly affected either by precision or by area raids accounted for between 90 and 95 per cent of the industry's capacity at the outset of the campaign.

25. The campaign was a joint effort of the three air forces - Eighth, Fifteenth, and Royal Air Force. Table 10 presents the attack effort of the three air forces. It must be noted that a strict breakdown between American precision raids and RAF area raids is incorrect

in this campaign: RAF raids on Schweinfurt, Elberfeld, and Annecy were precision raids and Eighth Air Force raids on Stuttgart and Leipzig were industrial area raids.

26. In all, 51 raids affected the bearings industry. Forty raids were directly aimed at 13 bearings plants in Germany, France, Italy, and Austria, a total of 4,015 sorties by Eighth AF, Fifteenth AF, and RAF planes. The total weight of bombs dropped was 12,149 tons, of which 7,990 tons, or 25,758 bombs were HE, and 4,159 tons, or 599,881 bombs were incendiaries. Of these totals, 4,957 tons, or 9,744 HEs and 2,976 tons or 582,854 IBs were dropped on Schweinfurt; these quantities represent 65.2 per cent of the total tonnage, or 62 per cent of the HEs and 71.5 of the IBs. The total hits of HEs (no reliable figures on IB hits were obtainable) reached 1,073, of which 642 were on Schweinfurt targets.

27. An additional 11 attacks were made upon areas in which important bearings plants were located, mainly Stuttgart and Leipzig. Six thousand two hundred and seventeen tons of HEs (10,717 bombs) and 4,536 tons of IBs were dropped.

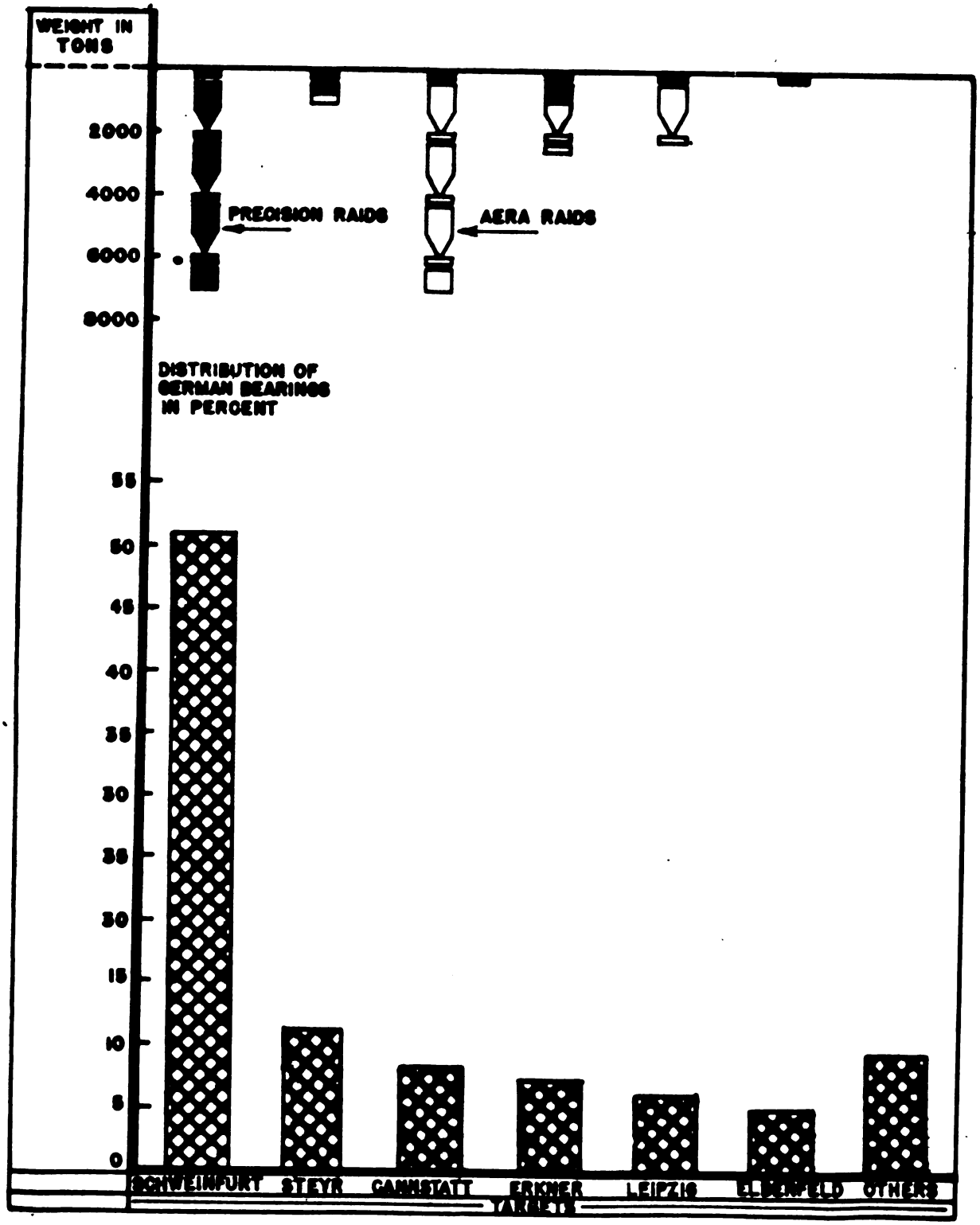
28. In the course of the attacks, 265 bombers were lost and 1,314 were damaged; as a partial balance, 549 enemy aircraft were destroyed.

Summary of Damage Data (See Exhibit B)

29. The total damage to the bearings industry as a result of the raids directly aimed at bearings plants may be estimated at 1,709,000 sq ft of buildings totally destroyed, 2,315,000 sq ft heavily damaged and 3,653,500 sq ft lightly damaged. Over 1,600 machines were destroyed and another 4,000 damaged. Casualties at plants numbered 387 killed and 198 wounded.

GERMAN BEARINGS TARGETS

WEIGHT OF BOMBS TO PERCENTAGE OF BEARINGS PRODUCTION



SOURCE: SONDERRING WOLZLAGER

FIGURE 5

TABLE 10

BOMBING EFFORT BY AIR FORCES

Against Plants, or Areas Including Bearings Plants

	Eighth Air Force	15th Air Force	RAF	TOTAL
Precision Raids	16	8	16	40
Sorties	2,409	668	938	4,015
Total Tonnage	6,457	1,868	3,824	12,149
HEs Dropped	17,993	5,951	1,814	25,758
Tons of HE	4,744	1,631	1,615	7,990
IBs Dropped	28,548	2,263	569,070	599,881
Tons of IB	1,713	237	2,209	4,159
Aircraft Lost	190	20	55	265
Aircraft Damaged	1,219	45	50	1,314
Area Raids	4	1	6	11
Sorties	294	87	2,529	2,910
Total Tonnage	681	261	9,812	10,754
HEs Dropped	2,542	1,044	7,131	10,717
Tons of HE	495	261	5,462	6,218
IBs Dropped	2,534	0	1,729,679	1,732,213
Tons of IB	186	0	4,350	4,536

• 13 raids made by less than 10 planes each

(Source: Operational Reports of the three Air Forces)

TABLE 11

DENSITY OF HITS

DATE	TARGET	TARGET AREA ACREAGE	TARGET AREA HE HITS	TARGET AREA DENSITY	PLANT AREA ACRES	PLANT AREA HE HITS	PLANT AREA DENSITY	% DESTROYED
17-8-43	FAG, Schwein	57	76	1.3	22.8	47	2.1	8%
	VKF 1	7.5	1	.1	4.9	1	.2	3%
	VKF 11	16.5	3	.2	13.1	2	.2	0
14-10-43	FAG, Schwein	57	92	1.6	22.8	27	2.1	4%
	VKF 1	7.5	20	2.7	4.9	18	3.7	22.5%
	VKF 11	16.5	31	1.9	13.1	18	1.4	20.2%
February	FAG, Schwein	57	79	1.4	22.8	23	1.	6%
1944 (3	VKF 1	7.5	17	2.3	4.9	11	2.2	18.4%
raids)	VKF 11	16.5	9	.5	13.1	5	.4	1.8%
23-2-44	Steyr	32.5	12	.4	11	4	.4	20%
21-2-44	Stuttgart	4.7	6	1.3	3.2	3	.9	11%
25-2-44	Stuttgart	4.7	10	2.1	3.2	4	1.3	28%
8-3-44	VKF Erkner	26	150	5.7	----	--	---	----
March 44	FAG, Schwein	57	39	.7	22.8	7	.3	1.2%
(2 raids)	VKF 1	7.5	0	0	4.9	0	0	0
	VKF 11	16.5	5	.3	13.1	4	.3	1.5%
2 Apr 44	Steyr	32.5	22	.7	11	11	1	----
April 44	FAG, Schwein	57	81	1.4	22.8	64	2.8	29%
(2 raids)	VKF 1	7.5	5	.7	4.9	3	.6	4.2%
	VKF 11	16.5	0	0	13.1	0	0	0
7-7-44	DKF, Leipzig	6.1	8	1.3	----	8	---	1%
20-7-44	DKF, Leipzig	6.1	0	0	----	0	---	0
16-7-44	Stuttgart	4.7	0	0	3.2	0	0	0
July 44	FAG, Schwein	57	76	1.3	22.8	56	2.5	10.1%
(2 raids)	VKF 1	7.5	2	.3	4.9	1	.2	----
	VKF 11	16.5	19	1.2	13.1	6	.5	13.7%
9-10-44	FAG, Schwein	57	48	.8	22.8	14	.6	1.7%
	VKF 1	7.5	2	.3	4.9	1	.2	----
	VKF 11	16.5	36	2.2	13.1	18	1.4	9%
16-10-44	Steyr	32.5	0	0	11	0	0	0

(Source: Damage Reports Prepared by Plant Manager)

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The amount of damage to stocks, instruments, and installations cannot be measured; the damage claims of German firms as a result of these raids, however, totalled 110 million Reichsmarks.

30. Damage resulting from area raids was not so extensive, and may be estimated at 500,000 sq ft of building space lost. Damage claims by the Germans for this destruction of plant, as well as for the considerable loss of stocks and equipment, reached 37 million Reichsmarks (of which 27 million were for the February raids on VKF-Bad Cannstatt.)

31. The total cost of damage thus amounts to 150 million Reichsmarks. The total for building destruction compiled from plants records--a little over 2,200,000 sq ft -- may be checked with the result of a Sonderring Waelzlager survey as of 10 October 1944. The bearings firms at that date reported a total loss of productive floor--space amounting to about 2,500,000 sq ft. These figures compare with a total pre-raid floor space for the industry of almost six million sq ft. The 1,600 machine tools known to have been destroyed equal a minimum percentage of destruction of 12½ per cent of the approximately 13,000 machine tools in inventory in August 1943; the 4,000 damaged constitute another 30 per cent. The disparity between these percentages is one of the striking facts about the damage: to the 50 per cent of buildings destroyed and additional 50 per cent heavily damaged, these figures of 12½ per cent and 30 per cent for machine tool destruction and damage present a significant contrast.

32. The intensity of the raids, and their accuracy, varied greatly. Surveying the results, it may be pointed out that the attacks were heavy enough to knock out completely such small plants as SRO, Annecy, and Ebelsbach; to put out of operation for a considerable period of time plants of medium size, such as the Steyr plant or the VKF plants at Stuttgart and Berlin/Erkner; and partially to disrupt production in the large Schweinfurt plants. Table 11 attempts to reduce these various factors to a common denominator of number of bombs per acre. Only HE hits are counted, since figures for IB hits are completely unreliable. The last column on percentage of floor space destroyed is included as a measure of the extent of destruction. Despite the absence of any mathematical correlation, the direct relationship between density of hits and intensity of damage is clear.

Nature of Damage

33. The following observations may be made about the nature of the damage inflicted. (The subject may be studied further in the "Interim Report on the Schweinfurt Investigation" in the Physical Damage Report 18 on the Kugelfischer plant at Ebelsbach, and in the Reference Notes 3, 4, 5 and Exhibit A - plant Layouts and Physical Damage, Schweinfurt.)

Damage to Buildings:

34. In half a dozen cases, as much as 20 per cent of the floor space of a plant was destroyed, and in half a dozen more the destruction reached 10 per cent. The three most thorough feats of bombing were at Annecy, where well over half the plant was destroyed, at Stuttgart, where half was destroyed, and at Ebelsbach where two-fifths were destroyed. In each case, a compact plant was the target; a more sprawling factory like Steyr or Kugelfischer/Schweinfurt could absorb more bombs with a lower density of damage.

35. The causes of damage to buildings depended on the type of construction. Wood frame buildings are obviously more susceptible to fire damage than are concrete or steel buildings. Steel frame buildings, relatively lightly affected by fire of fragmentation, were affected by earth shock. Concrete buildings proved most susceptible to blast. The following table, analysing causes of damage to Kugelfischer, illustrates these points, but should not be taken as a definite statement applying to bearings plants in general:-

TABLE 12

ANALYSIS OF CAUSES AND EXTENT OF BOMB DAMAGE
BY TYPE OF CONSTRUCTION
(Kugelfischer, Schweinfurt)

Type of Construction	Reinforced Concrete Frame	Masonry Load-Bearing Walls	Steel Frame	Wood Frame	AVERAGE
% of Total Floor Area	62%	10%	20%	8	---
Blast	65%	60%	30%	30%	54%
Fragmentation	2%	5%	5%	3%	3%
Earth Shock	10%	8%	50%	15%	18%
Fire	23%	27%	15%	52%	25%
	100%	100%	100%	100%	100%

(Source: Plant Damage Reports and Analysis by USSBS Experts)

Damage to Equipment:

36. Machine tools proved less susceptible to damage than was anticipated. Only in the heaviest and most accurate raids on concentrated targets did destruction of machine tools run as high as twelve per cent (Ebelsbach, 21 July 1944 -- 12 per cent destroyed; Steyr, April 1944 -- 10 per cent destroyed.) In such raids and others; building damage ran much higher: at Ebelsbach 40 per cent destroyed or structurally damaged, and at Steyr 70 per cent damaged to some degree.

37. For the Schweinfurt raids, the percentage of machines destroyed per raid averaged well under 5 per cent, and the percentage damaged under 10 per cent more. Almost all damaged machines were repaired in less than four months after a bombing incident and the bulk of them in less than two (Figure 6, Immobilization of Kugelfischer Machines) Kugelfischer, the hardest hit firm, had 534 machines destroyed in all the Schweinfurt and Ebelsbach raids, or one-eighth out of a total of 4,177 machines on hand during the period. The machines destroyed were exceeded by those added, both Kugelfischer and VKF having more machines after the raids than before.

38. The Allied expectation of destruction of machine tools involved an over-estimate of their sensitivity to damage:

a. Damage from debris and flying fragments was slight, falling roofs often serving to protect machines rather than to harm them.

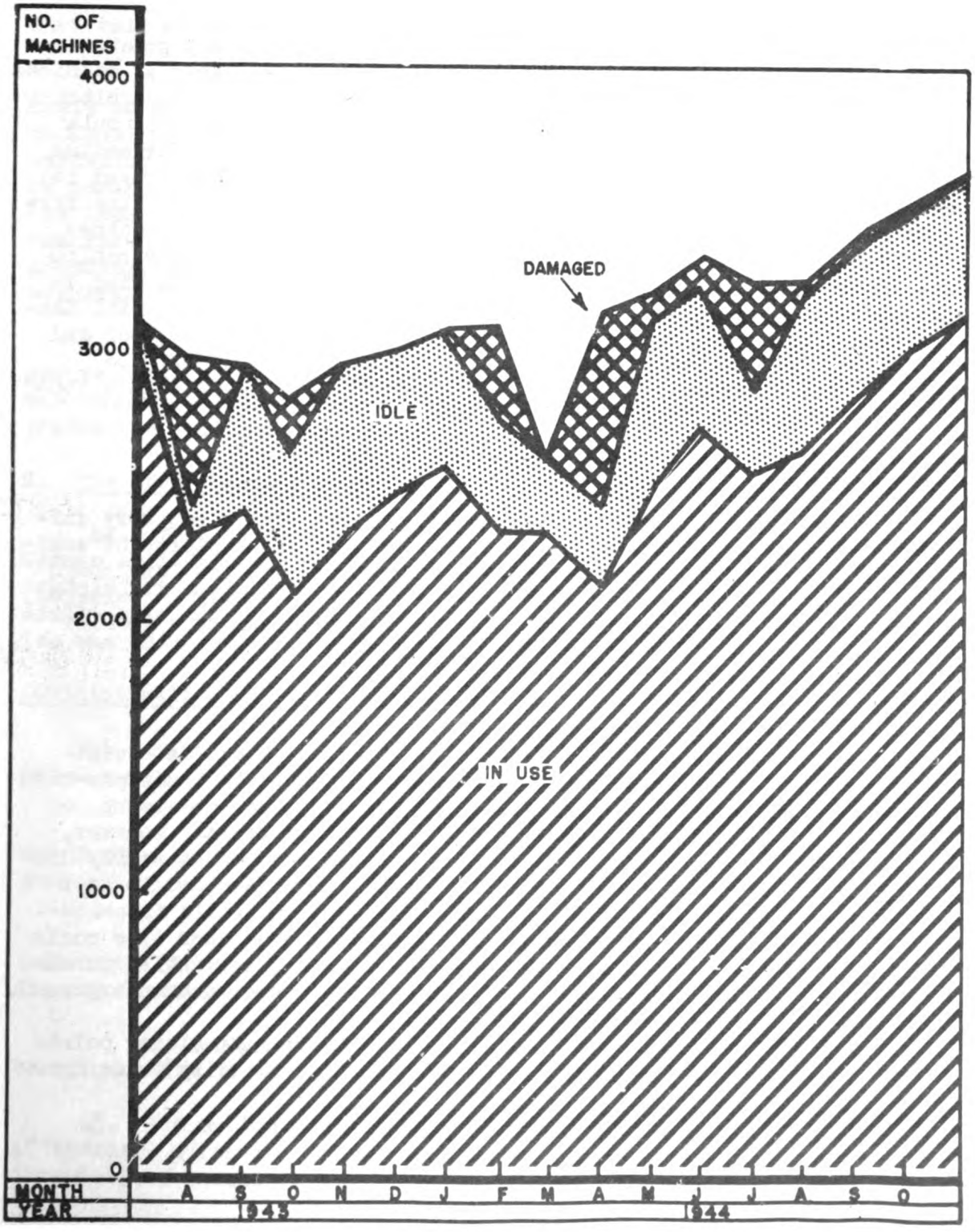
b. High explosive bombs failed to destroy heavy machine tools except in case of direct hits. Electric gear was the chief vulnerable point on such machines. The most effective bombs were those fused to explode between roof and floor or to destroy the floor and collapse the machines into the cellar or the floor below. Without collapse of floors or direct hits, machines could usually be set in order after cleaning and minor adjustments on the spot. Dust, fragments of plaster, and other building debris required care that the machines be cleaned before set in operation, to avoid internal damage. Spindle bearings were protected against such dangers with seals, and needed extensive cleaning only when in the immediate neighborhood of a bomb-hit. In general, blast-walls and shields proved excellent protection against widespread damage from single hits of high explosive bombs.

c. Fire damage was most effective. Machine tools containing a great deal of oil were susceptible to fire damage that was exceedingly difficult to repair. Machines heated by incendiaries or by building fires were twisted or broken in their frames and parts by the water used in fire fighting.

d. The greater destructiveness of fire over blast meant that

IMMOBLIZATION OF KUGELFSCHER MACHINES

JULY 1943 - NOV. 1944



SOURCE KUGELFISCHER PLANT DATA

FIGURE 6

buildings with wood floors and supports multiplied machine damage, either through direct effects of fires or through collapse of machines through the floors. Buildings of reinforced concrete meant that fires were easier to quench and effects of bombs were in general limited to the immediate vicinity of the hit.

39. The variation in destructiveness of bombs was very great, so that it is impossible to state any coefficient of the number of machines destroyed or damaged per bomb hit, except as a misleading and arbitrary average. A single bomb in the 13 April 1944 raid destroyed the bulk of the machines in Kugelfischer's ring-grinding department for medium bearings. Another single bomb, in the February attacks, destroyed 161 machines in VKF's machine storeroom in Works 11 as a result of the fire that broke out. Other bomb hits did virtually no damage to machines, and this is true of exploded bomb as well as duds: bombs penetrating the floor would crater with very little effect and bombs exploding in the roof would collapse the roof on machines with only superficial damage resulting. Even in cases of bombs exploding between the roof and the floor, (on the whole most effective), machine damage would be slight where blast walls, trucks of components, or other machines stood between the bomb and the surrounding tools.

Damage to Stocks

40. Raw material, such as bar, tube, or wire steel, was very difficult to damage, and losses were insignificant. Among stocks of semi-finished and finished bearings, damage from exposure, fire, and rough treatment was considerable. Such components could usually be salvaged, however, since balls, rollers, or rings could be ground to a smaller size and re-finished.

VULNERABILITY OF DEPARTMENTS

41. Vulnerability of departments of a bearings plant is essentially a matter of the machines used in the departments. Thus, pre-raid theories of the desirability of aiming at turning, heat treatment, or hardening, and grinding were quite sound. These processes, however, comprise the main operations of a bearings plant and do not really discriminate or provide a basis for selecting aiming points. Only heat treatments occupies a distinct area of a factory; and while in peacetime plants it will normally be identifiable by the monitor type roofs and the ventilator outlets, it is perfectly possible in wartime to camouflage ventilating arrangements or even put heat treatment underground.

42. Though bearings plants really offer no separate aiming points except "Machine Shops", the following points of sensitivity to damage have been observed:-

a. The more complex and valuable the machine, the harder to replace; thus damage to departments using automatics will be most effective. The automatics destroyed in the 21 February 1944 RAF raid on Stuttgart were never replaced and similar destruction in the Schweinfurt raid of 19 July 1944 permanently crippled medium-bearing production.

b. The dies used in stamping retainers were extremely difficult to make or replace; their destruction in the October 1943 attack on Kugelfischer caused greater replacement problems than destruction of hardening ovens or ball grinding machines. Heat treatment facilities in ceramic or other factories could be adapted to bearings manufacture; and less specialized grinding machines, while requiring more man -and machine- hours for lower quality work, could also be adapted to ball grinding. But die-making requires both time and the most skilled workers.

c. Damage to utilities during raids hindered fire-fighting and re-building as well as production. Destruction of power and fuel was thus as effective in reducing production as was direct damage to productive facilities.

B. <u>The Enemy Counter Measures</u>

43. The October 14 attack on Schweinfurt provoked a crisis in the German anti-friction bearings industry; coming on top of the August Schweinfurt raid and the September raid on CAM Paris, it confirmed the widely held suspicion that an offensive against German bearings production was under way. The Reich moved swiftly to organize its defenses.

<u>Administrative Controls</u>

44. Between October 15 and October 26, the Speer ministry promulgated a series of decrees, having the following effects:-

a. Extension of full control over the bearings industry to the Sonderring Waelzlager, enabling that body to control all stocks, production, and delivery of bearings.

b. Establishment of a General Commissar for the bearings industry - Philip Kessler - to act as expediter of reconstruction and dispersal efforts.

c. Assignment of the highest priority in German industry to bearings, with first call on labor, raw materials, and machinery.

45. The Sonderring immediately placed a suspension on deliveries of bearings effective for all but the most urgent needs, called for an inventory of stocks in the hands of producer and user firms, and set up

machinery for the handling of orders on an industry-wide basis. At the same time, measures to reduce demand for anti-friction bearings, such as substitution of plain bearings and redesign of equipment to eliminate bearings, were intensified, and a program of expanding capacity, dispersing plants to new locations, and placing them underground where possible, was given energetic support.

46. The establishment of a control body to correlate immediate demand with available productive capacity was essentially an administrative problem. Prior to the air attacks, a system of such controls had not been in effect in Germany. As we can see from Chapter VII, which discusses the detailed workings of the procedure, it offered administrative problems similar to those handled in the American War Production Board and the British Ministries of Supply. The brilliant success of the Sonderring is partly due to the ability and energy of its leading figures, but partly, also, to the compactness of the industry, with only a few important firms not widely scattered over the Reich.

47. More distinctive methods had to be applied to the solution of the immediate problems the industry faced when the Germans realized it was marked for obliteration by the Allied high command.

Restoration, Dispersal, and Expansion of Capacity

48. Whereas repair of plants damaged in the August raid on Schweinfurt had been undertaken solely by the firms affected, the approach after the October raid was a unified plan for which responsibility was shared between the Kessler organization and the Sonderring Waelzlager. Kessler's group was responsible for repair, reconstruction, and expansion of capacity, in terms of machines and buildings, but relied on the Sonderring for cooperation and guidance in decisions, since the latter group were experts in the bearings field. In turn, the Sonderring received the backing of Kessler, who had the support of the Speer Ministry, in carrying out its own tasks.

49. The first step of the Kessler Organization was to set up a group within it to supervise repair to buildings damaged under attack, and to prepare dispersal sites which would replace other plants. To accomplish these tasks, both the Todt Organization and local labor were employed.

50. A second step was the establishment of a central shop for the repair of machines damaged in attacks on bearings plants. The plant of Konig and Bauer, Wurzburg, was selected for this purpose. At the same time, Kessler chose staff members to supervise repair to gas, water and electric installations (damaged in nearly every attack) and other personnel to facilitate labor procurement for the Sonderring Waelzlager.

TABLE 13

ANTI-FRICTION BEARINGS DISPERSAL PLANTS

	VKF Schweinfurt	VKF Cannstatt	FAG	Steyr	DKF	Muller	Kling
1942 1st Half							
"		Ebingen					
2nd "	Liebauthal	Stuttgart					
	Elfershausen	Marbach					
1943 1st "							
July							
August							
September		Remmelsbach					
October							
November			Erlangen	Letten			Kauterbach
December	Bayreuth		Kirchheim				
		Reutlingen	Zell				
1944 January	Mainleus	Neckarten-zlingen	Hirshaid				
February			Landeshut	Ried		Anspach-untererdich	
			Schwartzen-bach				
March		Riederich	Edelsbach				
April		Neuenstadt	Fraureuth	Turnberg			Tiefenbach
				Reseman			
	Grottstadt						
May	Iphofen						
	Fuchstadt			Ling	Meerane		
			Forsheim				
June			Bamberg				
		Kirchheim UT	Gundelsheim				
July		Metzingen	Ebern				
August					Zwickau		
September				Rottenmann			Albshausen
October	Schauenstein						
November			Wellen	Melk			
December	Neckar-Zeingen						Steindorf
1945 1st Quarter		Stuttgart					

(Source: Plant Reports)

51. In these activities, as well as in the efforts at dispersal and expansion shortly to be described, Kessler exploited as far as possible the high priority designation of the bearings industry. His task was made lighter by the fact that he, as the first of the all-powerful "czars" for specific fields, had no competitors with whom to clash.

52. Although energetic efforts were made to repair plants damaged in the raids of October and February, an early decision was made to replace knocked-out departments at dispersal sites, rather than those in the original plant areas. By so doing, the industry, which were being slowly carried out prior to the October raids, were thrown into high gear. Between November 1943 and August 1944, 32 new production sites were built or converted into manufacturing units of complete bearings or component parts. Particulars about these dispersals are presented in Table 13. In addition a number of other places were taken over for use as storage depots and for administrative purposes.

53. As a previous section has pointed out, the Sonderring since early 1943 had been working on a plan to double the capacity of the bearings industry to build up production to over 14 million bearings monthly. Due to the destruction of many machines in air raids and the need for duplication of some machines under the dispersal program, the expansion program was drawn upon to fill the breach opened by the combined bomber offensive. However, confident that the dispersal had achieved near impunity to attack in the spring of 1944, Kessler sponsored a new plan, with the more ambitious goal of over 15 million bearings monthly. Adopted in May, this plan was intended to achieve its object by the following May. It was carefully worked out with the Sonderring and individual firms, who consolidated requisitions for the labor, materials, machines and other equipment required. This ambitious goal was not attained, mainly because continued raids interfered with the organizational efforts, but in part, also, because the demand picture changed. The fact that the Germans continued to set their sights high helped bring about rapid recovery in the industry during the summer of 1944, however, and testifies to their recovery from the fear of collapse so freely expressed in the fall of 1943.

54. A distinctive feature of the dispersal and expansion effort was the plan of moving the actual equivalent of the pre-raid output under-ground. The two main underground sites were the caves at Neckarzimmern, for VKF, and the new excavations at Wellen on the Mossele River, for Kugelfischer. Other firms also developed underground sites - Steyr at Linz and Melk, Erkner at Rudersdorf, and Mueller at Ansbacn.

55. These underground works were planned as integral producing units, not merely departments. They were to have the original capacity

of the parent firms - the Wellen plans, for example, called for 1,291,200 sq ft of productive floor space, in comparison with the Kugelfischer Schweinfurt plant's 1,301,960 sq ft in August 1943.

56. With one hundred per cent of the needed production underground, as scheduled in the plan, the remaining equivalent capacity above ground would have been a cushion which air attack might totally obliterate without causing shortages of bearings to worry the production of armaments. However, the slowness of machine deliveries and the extra time required to prepare underground factories for bearings production, together with the convenient availability of buildings well suited for the manufacture of bearings, such as former textile and ceramic factories, resulted in the greater number of dispersal sites developed being still above ground by the end of 1944. The urgency of the situation required speed in the setting up of dispersed plants since a temporary immobilization and under-utilization of machines would have to be undergone during the period of dispersal. Indeed, the fact that the dispersal efforts and heavy air attacks came all together in the spring of 1944 brought production down to critical levels in this period. Along with the dispersal program, efforts were made at sub-contracting the production of bearings parts to manufacturers in other industry. This might be considered a type of dispersal or expansion. However, the results were not fruitful. In the outstanding example, Kugelfischer sent out 700,000 forged rings to be processed in soft operations in the automobile industry's "Hilfsaktion", a sub-contracting organization. This was done in the middle of 1944, but by the end of the year only 15,000 had been worked.

Stocks

57. To meet the immediate needs of the crisis in the fall of 1943, the Sonderring Waelzlager exploited available stocks of bearings while the industry was being re-organized to defend itself against attack.

58. No planned stock piles had been built up within the bearings industry in the pre-war or in the early years of the war. A policy of building up stocks was not possible, since the expansion of bearings production had difficulty in keeping up with the increasing demands of armaments manufacturers. Kugelfischer's end-of-year inventory, for example, showed an average of 1,658,000 bearings on hand in the five years ending 31 December 1942, which is slightly lower than the average monthly output for that period, approximately 1,800,000 bearings. According to Hermann Lange of the Sonderring one month's supply was the normal stock of bearings in the hands of producers. These bearings were mostly committed to current orders; an investigation by the SRW in the summer of 1942 found only 1.2 million uncommitted bearings in the hands of producers. Most of these were types needed only for

peacetime production. The same source reported supplies in the hands of sales agents, especially of the two major firms, VKF and FAG, at two to three million bearings, chiefly types in demand for repair needs and small orders; thus, less than a third of a month's production for the whole industry was available in the hands of sales agents.

59. An inventory of the Wehrmacht's stocks taken 1 January 1944 showed a surplus of 500,000 bearings for replacement above the anticipated 12 months' need, mainly for tanks and motor vehicles. An air attack on the army's depot near Magdeburg at the end of January 1944, however, was so destructive that only 200,000 could be released for other users.

60. On the other hand, stocks in the hands of consumers were much more considerable, and these were being inventoried and drawn on before the 1943 raids. In March 1942, the Luftring Bfs surveyed the stocks of aircraft manufacturers and released for redistribution one million bearings which were in excess of the six months' supply allowable for any type; of these, half could be re-allocated. The SRW circularized 680 firms in summer 1942, who placed at its disposal 1.6 million bearings, of which 60 per cent were redistributed; a similar program in the summer of 1943 uncovered 2.5 million bearings - of which 800,000 could be reallocated. Complete inventories of stocks of bearings were not taken, but Sonderring officials estimated the consumers' stocks to have been from six months to one year's supply in the various industries, with even tank producers having six months' stocks

61. Immediately after the August 1943 raid, an inventory check, with the help of the Armament Inspection Offices (Ruestungsinspektionen) disclosed that, in general, users had stocks amounting to six months' needs. After the October 1943 raid, the SRW initiated its "Mobilization of Anti-Friction Bearings Reserves". Approximately ten thousand firms submitted certified statements of the bearings on hand as of 1 November and the average monthly use. They were each allowed a normal stock varying between three months' and six months' supply (in the case of aircraft), depending on the length of the firms production cycle. Bearings above this normal stock were frozen for distribution by the SRW, which did not draw on the normal stock, save in rare cases of bottlenecks; the committees of the various industries, however, were encouraged to balance their member-firms' stocks without reference to the SRW. The accompanying table shows the results of the successive "Mobilizations":-

TABLE 14

MOBILIZATION OF BEARINGS RESERVES

Report Date	Surplus Bearings Reported (Millions)	Bearings Redistributed by SKF (Millions)
1 November 1943	8	4
1 March 1944) 1 July 1944)	8	4.5
1 January 1945	4	0

(Source: Records of the Sonderring Waelzlager)

62. Though the original plan called for quarterly inventories, it proved impossible to handle the administrative detail involved, and the March 1944 inventory had to be run over into that for July 1944. The January 1945 inventory was never completed. The March and July returns were only to include bearings not previously reported; hence the reports did not overlap and their totals can be added. The 8.5 million bearings redistributed represent slightly over one month's output for the anti-friction bearings industry; they were used mostly for satisfying repair needs and small orders, or in answer to Einbruchs-meldungen ("Advices of Interruption".) The slightly lower percentage proving useful among bearings announced in 1943 resulted from the presence of a considerable number of types no longer usable for war production in the hands of peace-time producers. The distribution of sizes was the customary one; firms using extra-small and small bearings had ample or surplus stocks, while only 500-600,000 medium bearings were made available.

63. During the period between the October 1943 raid and the end of the year, bearings deliveries were in general restricted; consumers were forced to rely on their stocks-on-hand except in the cases of urgent need. By the first of January, when deliveries were released, the bearings firms had on hand about 12-15 million bearings or almost two months' supply. The existence of this stock enabled the industry to get through the critical first half-year of 1944, when production dropped under the burden of attacks, reconstruction, and dispersal. The following data from the Kugelfischer firm show that while the output curve dropped violently, the delivery curve was fairly regular and showed how the shock for consumers was cushioned, though at the expense of the bearings firms' stocks:-

TABLE 15

KUGELFISCHER* OUTPUT, DELIVERY STOCKS, 1944, (1,000 pieces)

	Output	Delivery	Stocks at end of Month (**)
Jan 1943	1,904	-----	1,514
Jan 1944	2,041	1,474	5,041
Feb 1944	1,687	1,759	4,949
Mar 1944	1,428	2,195	4,085
Apr 1944	844	1,169	3,656
May 1944	975	1,633	2,856
Jun 1944	1,460	1,466	2,455
Jul 1944	1,618	1,835	2,142
Aug 1944	1,621	1,777	1,979
Sep 1944	1,896	1,820	2,057
Oct 1944	1,897	2,023	2,073
Nov 1944	2,042	1,851	2,245
Dec 1944	1,799	2,084	2,139
Jan 1945	1,775	?	2,452 (***)
Feb 1945	1,250	?	2,769

*) Kugelfischer furnished only available data.
**) The columns do not check exactly laterally because of time lag between production at the plant and delivery from the contral depot.
***) In early 1945, transportation difficulties prevented delivery and resulted in rise of stocks.

(Source: Kugelfischer Records)

Substitution and Redesign

64. One of the most important counter-measures adopted by the Germans was the effort to shrink demand for anti-friction bearings through the use of substitutes; in most cases this involved redesign of equipment. Occurring at the same time that emphasis in aircraft construction shifted from bombers to fighters, and then to jet-propelled aircraft, - in each case resulting in lower needs for bearings per unit - the substitution program materially reduced demand even while production of aircraft and weapons was rising.

65. "Substitution" included three distint counter-measures:-

a. Replacement of anti-friction bearings of complex construction or in short supply by other anti-friction bearings of simple construction or in ample supply.

b. Replacement of anti-friction bearings by specially manufactured substitute friction bearings of the same outer dimensions.

c. Replacement of anti-friction bearings by plain bearings designed and built into equipment by end-product manufacturers.

66. The first measure offered only slight relief from the demands on the anti-friction bearings industry, and was a matter of shifting the impact of demand within the industry; it was directed by the Sonderring Waelzlager. The other two shifted demand outside the anti-friction bearings industry; they were supervised by the "Amtsgruppe Fertigung im Technischen Amt des Reichsministers fur Rustungs und Kriegsproduktion". ("Group on Manufacturing in the Technical Office of the Reichs Minister for Armament and War Production"), headed by Colonel Schaede. (Special Committee for Plain Bearings) For the second sort of substitution, there was specifically the Sonderring Gleitlager, an organization of producers manufacturing a special type of friction bearing, headed by Koehler of Demag, Wetter/Ruhr, established in November 1943 to supervise study and establishment of already planned production.

67. Replacement with simpler bearings or bearings in good supply was primarily a way of meeting temporary bottlenecks, and helped diminish the gap between supply and demand only insofar as simpler types of bearings, once installed, could be manufactured more efficiently and abundantly.

68. After the first attack on the bearings industry in August 1943, Schaede's office began investigating the possibilities of substitution. In the directive of 19 November 1943, setting up the Sonderring Gleitlager, the expectation was expressed that in a relatively short time around 2.5 million pieces monthly would be available as substitutes for anti-friction bearings, with the additional hope that eventually 40 per cent of the anti-friction bearings might be replaced by the new product.

69. Achievements up to July had been slight. Difficulties with labor and machines had been encountered; there was no trained labor for the new industry, and the Sonderring Walzlager held high priority for new machines which it was reluctant to waive. In contrast, then, to the contemplated 2.5 million bearings there was a June 1944 production of 132,700 plain bearings all in the size range under 28 mm outer diameter. This contrasts with the Walzlager output for June in the same size range of 4,449,444 bearings. This size range, however, was the only one in which anti-friction bearings supply already exceeded demand.

70. The Sonderring Walzlager's survey of substitution possibilities of specially manufactured plain bearings had yielded the general result

that in number of pieces the prospects were high; but that for the types and sizes in which bottlenecks existed, the possibilities were low. Specifically, designers were willing to substitute plain bearings for small ball-bearings - in which supply was ample - but less willing or unwilling to substitute for middle-sized cylinder-, taper-, and spherical-roller-bearings, or for thrust bearings, where supplies were short, because of technical deficiencies of plain bearings. Panzer firms, for example, were willing to substitute in only five out of 340 types, with a monthly use of 19,400 bearings, in current designs; and in 19 additional types using 95,500 bearings monthly when new designs were made. In weapons, airframes, and electrical equipment, (in which the bulk of the demand was for small bearings), substitution possibilities were more promising, covering a range of 30 to 60 per cent of the bearings points.

71. The Sonderring Gleitlager continued to plan for replacement of millions of anti-friction bearings, and did show a rising output in the second half of 1944, as these approximate figures furnished by the former chief of the Sonderring, Kr. Koehler, show:-

TABLE 16

OUTPUT OF GLEITLAGER

	Date	Output
(1944)	June	132,700
	July	150,000
	August	250,000
	September	600,000
	October	900,000

72. This output continued, however, to be in the smaller size ranges; in the middle ranges, where shortages were serious, almost no plain bearings were produced. In 1945, for example, production of plain bearings in the size range 120-240 mm Outer Diameter (Mittellager B) was only 10,000 per month, in contrast with a Wallager output of 450,000 monthly and a monthly demand of about 600,000.

73. The relief afforded the anti-friction bearings industry by the war-nurtured friction bearings industry may be summed up in a quotation from a meeting at Schweinfurt on that subject, 4 January 1945, under the chairmanship of General Commissioner Kessler's Deputy, Dr. Seuffert, and signed by him:

74. "Inasmuch as there is any possibility of considerable

production of plain bearings in the first half of 1945, these will be received as welcome reserves; however, on account of the definite uncertainty of delivery dates, friction bearings cannot be considered in planning for the period."

75. The amount of relief afforded the anti-friction bearings industry by redesign, and by manufacture of plain bearings such as bushings, sleeves, etc, by equipment manufacturers themselves, cannot be stated in definite figures or even as a percentage. Instances of changes in certain types of equipment show, however, that the relief from this source was considerable.

TABLE 17

ECONOMIES IN ANTI-FRICTION BEARINGS THROUGH REDESIGN

Type of Equipment	AF Bearing Before Redesign	After Redesign (Oct-Nov 1944)		
		AF Bearing	Plain Bearing	Eliminated
Aero-Engines	(a)	(b)	(c)	(d)
DB 605/d	45	17	28	0
Jumo 213	94	46	48	0
Airframes**				
Ju 88	950	81	865	4
Ar 396	50	0	50	
Ju 188	989	128	861	0
Ju 352	918	173	745	0
Ju 388	1,056	369	687	0
He 219	530	26	504	0
Ar 96	186	70	116	0
Go 242	254	88	166	0
He 111	283	23	251	9
Fw 190	129	18	107	4
Me 262	43	0	43	0
Me 109	50	0	50	
Ar 234	178	46	106	26
Do 335	168	69	99	0
Guns				
Flakvierling 38 Lafette	52	8	5	39
Flak 2-cm Geb. 38 Lafette	49	4	45	0

736343 O-47-5

	(a)	(b)	(c)	(d)
Flak 3.7-cm 37	41	23	9	9
Flak 3.7-cm 43	58	8	24	26
Flak 8.8-cm 47	47	2	45	0
Searchlights, Firing Devices, Signal Equipment				
Flakscheinwerfer, 200 cm 43 k	80	39	41	0
Scheinwerfer 150 cm	49	16 ***	33	0
Flakrichtgeraet 40 A2	82***	17	65	0
200 W Langwellen-Sender SS	24	0	24	0
200 W FVK-Sender SS	25	0	25	
200 Watt Kurzwellen-Sender SS	24	0	24	0
Feldfernschreiber a	13	6	7	0

* In other types, there is definite information that anti-friction bearings were completely eliminated.

** The bulk of the Junkers, Heinkel, Arado, and Messerschmidt substitute bearings were made by the airframe manufacturers themselves.

*** Plus loose balls and loose rollers.

76. Although the program proved very successful for airframes, aero engines, weapons, and other equipment, the success was negligible for panzer and motor vehicles, where the difficulties over the supply of medium bearings were most serious. Dr Bailleul, the engineer from VKF who acted as the Sonderring Walzlager's technical specialist in bearings for tanks, estimated the number of anti-friction bearings per unit at only five per cent fewer in 1945 than in 1943.

77. Much of the reduction in use of anti-friction bearings in aircraft and weapons was the result of luxurious over-use of these bearings in earlier designs. Engineers from Kugelfischer and VKF admitted that many equipment designers, when confronted with a bearings point, simply looked up the anti-friction bearing with the proper specifications in the convenient and elaborate anti-friction bearings catalogs, rather than design a plain bearing for each new demand. The

original impulse toward economizing in the use of anti-friction bearings in designs came before the attacks on Schweinfurt, when the first American planes had been shot down and their designs showed that plain bearings had been used wherever the load and speed did not imperatively require anti-friction bearings. Thus, the program for redesign and substitution in aircraft dates from the middle of 1943. The successful program for weapons was carried through experimentally and embodied in actual construction in four months in the middle of 1944, in direct answer to a threatened shortage of bearings (Figure 7 - Economy in anti-friction bearings through redesign of equipment.)

Imports and Exports - Sweden and Other Countries

78. One of the measures taken by the Sonderring Walzlager in October 1943 was the suspension of bearings exports. Reports were requested of the outstanding orders and a careful study made of types and sizes included. Deliveries were eventually resumed in 1944, but were restricted to bearings not urgently needed in the Reich and in rare cases to repair items essential to avoid industrial breakdowns in occupied countries.

79. At the same time efforts were made to intensify the procurement of bearings from sources outside of Germany. The most important of these was Sweden. Production capacity in Switzerland was limited. The attacks on the RIV (Turin) and CAM (Paris) plants combined with the German policies of neglect and of stripping France and Italy of their skilled workers had eliminated the possibility of fruitful results from these countries. On the other hand, the imports from Sweden were one-seventh as large as the total output from German plants.

80. When the combined bomber offensive began, Germany was threatened with a reduction or cut-off of Swedish bearings, since the Allies from the beginning of the war had been maintaining pressure on Sweden to limit bearings shipments to Germany.

81. A diplomatic offensive accompanied the air offensive and resulted in the signing on 12 June 1944, of an agreement limiting the value of bearings to be shipped by Sweden to Germany in the next three months. On the termination of this pact, on 12 October, the Swedes were further persuaded to cease deliveries completely.

Actual Imports - Value and Composition

82. The following data on the value of German imports of bearings in 1943 and 1944 was obtained from the Sales Director of VKF, Herr Holz, who handled all German imports from SKF:

ECONOMY IN ANTI-FRICTION BEARINGS THROUGH REDESIGN OF EQUIPMENT

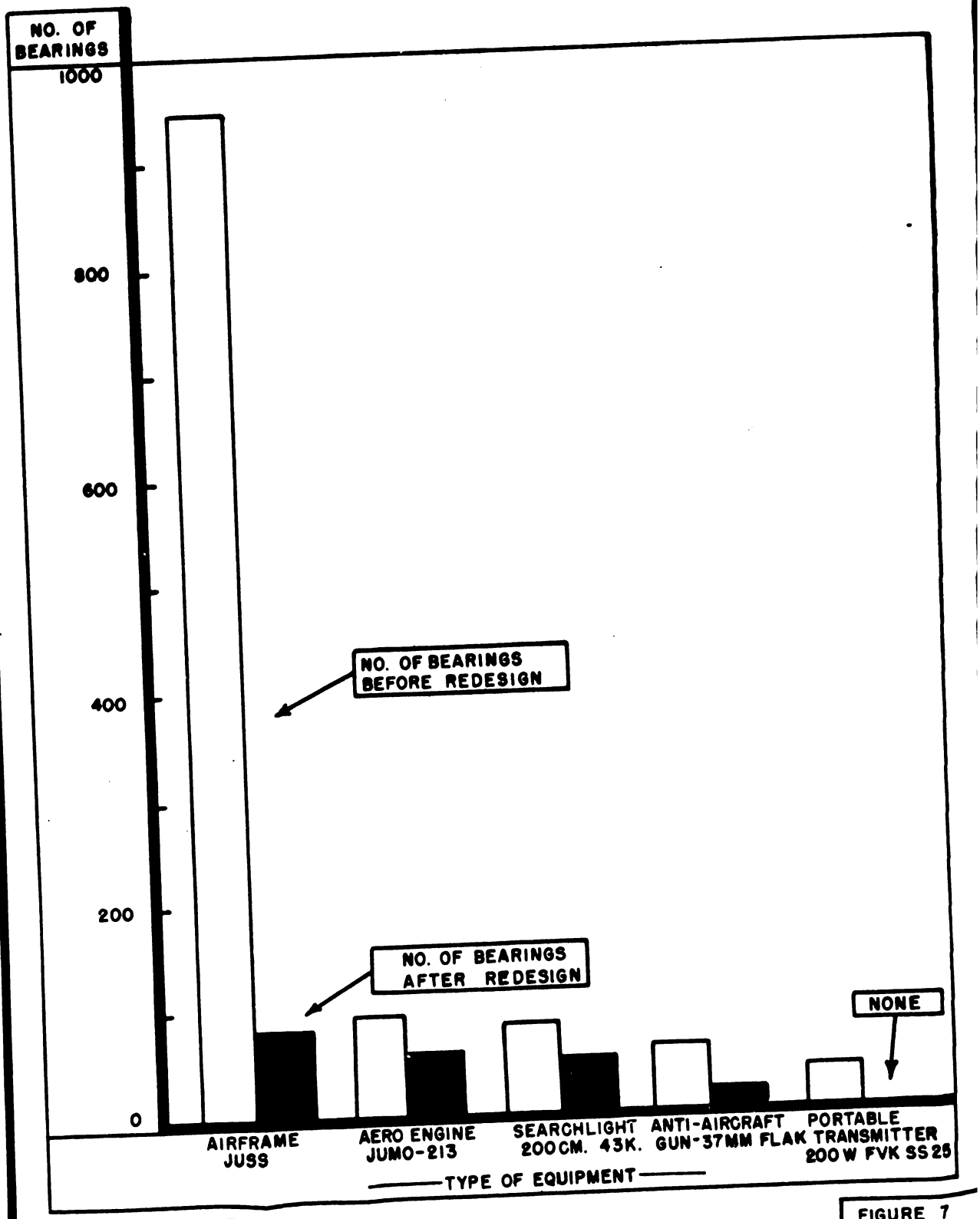


FIGURE 7

SOURCE: SONDERRING WOLZLAGER

TABLE 18

SWEDISH EXPORTS TO GERMANY, VALUE IN THOUSANDS OF KRONEN,* 1943-1944**

	1943		1944	
Month	Bearings	Bearings Machinery	Bearings	Bearings Machinery
Jan	3,183	----	5,099	----
Feb	4,551	----	4,072	56
Mar	7,601	----	1,861	310
Apr	2,159	----	1,276	----
May	4,887	----	1,421	----
Jun	6,102	----	196	----
Jul	2,311	----	805	----
Aug	1,340	472	707	----
Sep	4,030	124	608	----
Oct	2,527	19	?	----
Nov	3,610	63	---	----
Dec	7,088	475	---	----
Total	49,389	1,153	16,045	366

* Approximate 1940 value; 1 Swedish Krone equals U ¢ S 24

** The 1942 totals were 36.2 million Kroner for bearings; the amount for the bearings machinery was not available.

83. While the value of bearings sent to Germany by the SKF concern declined along the general lines of the agreement with the Allies, the sizes and types of bearings delivered, chiefly, special ball bearings for aircraft and special roller bearings for tanks and other highly important needs, were submitted in accordance with German priority designations, as the following excerpt from a telegram describing the German counter-effort indicates:

Stockholm, 3 July 1944

Telegram from Sweden to Dr Becker "Geheime Reichssache" - (Classified as top secret)

"A. Our experts, in the Goteborg discussions with SKF, have arranged the known German desires in three degrees of importance: Priority 1- the most important; Priority 11- types that must not be given up so far as possible; Priority 111- types which with help from SKF can be prepared in Germany. The distribution was examined by Dr Becker in his capacity as head of the SRW, and on grounds of defense

he raised a number of types to higher priorities.

"B. The discussions ending on 1 July in Goteborg have brought VKF to an agreement with SKF, the essence of which can be given as follows:-

"1) From the wishes in Priorities 1 a and 1 b, amounting to 1 million Kr worth of ball bearings, and 2.2 million Kr worth of roller bearings, ball bearings to the value of 1 million Kr and roller bearings to the value of 1.9 million Kr are to be delivered, in accordance with the submitted list of delivery dates ....

"6) The agreed proportion of 40:60 between roller and ball-bearings is not being followed, as the above orders show. If the Swedish government does not approve, the balance can be restored within the list of desired bearings.

"SKF is further ready to supply rings and cages instead of assembled bearings. This could mean, that through the taking over of manufacture of rollers in Germany and carrying through assembly there, the price of roller bearings could be reduced 20 per cent, so that a correspondingly higher quantity of roller bearings could be added in Germany.

"7) The quantities and types to be chosen are limited only by the total value of the trade agreement. Therefore, the German priority list includes aircraft bearings to the value of RM 700,000.... The Swedish promises for Lists 1 a and 1 b must be considered very satisfactory. The delivery promises fulfill our most urgent wishes as to date, which means a very considerable effort on the part of SKF in the present manufacturing situation ..."

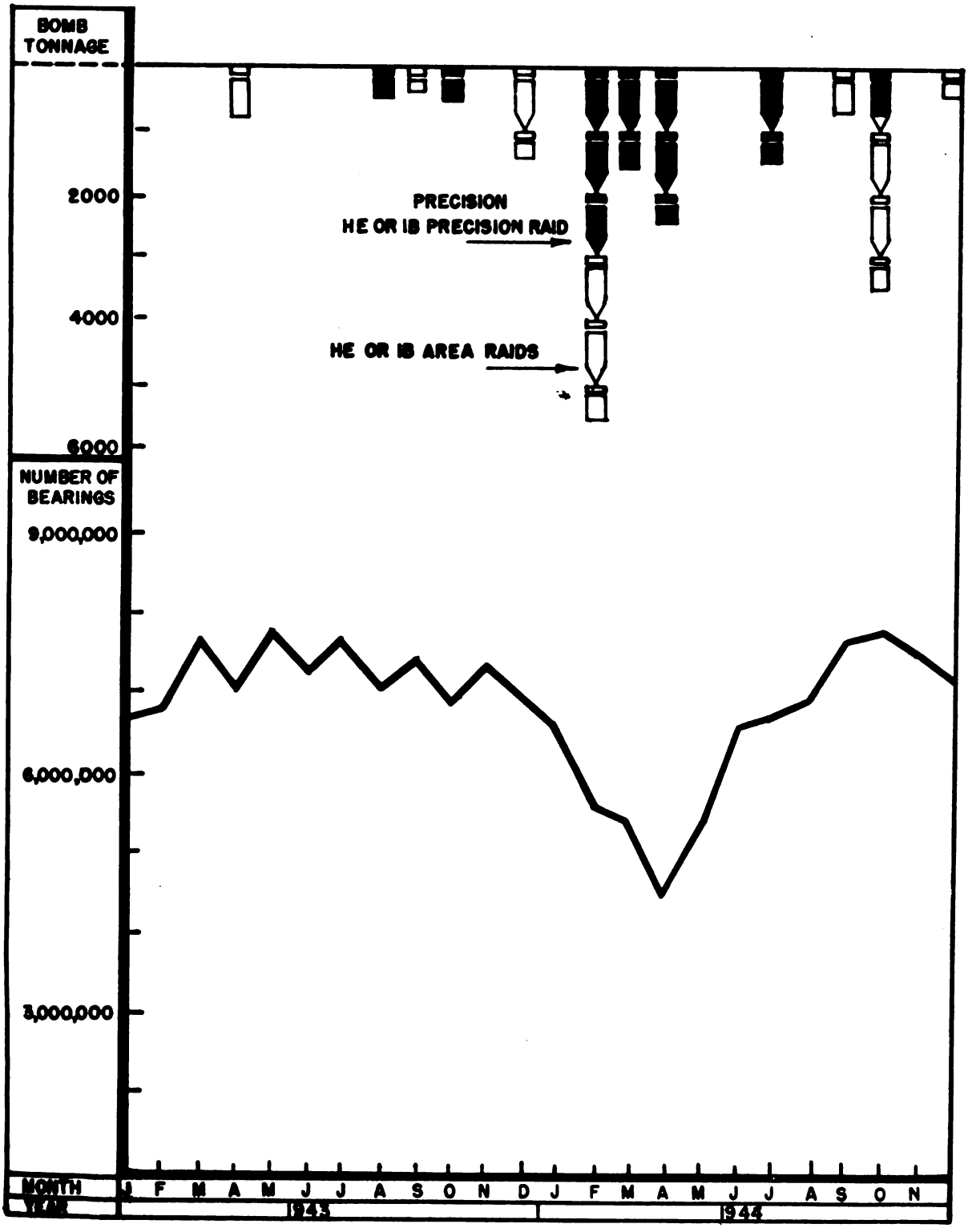
C. The Production Curves

84. The impact of the combined bomber offensive on the output of the anti-friction bearings industry may be seen in Figure 8 and from data in Table 19, which presents monthly index numbers based on the second quarter of 1943 as 100 per cent. The figures vary between firms, closely following the incidence of attacks upon their plants; the effects on the production of medium-size A bearings were sharper than those for the total output, including all sizes.

85. Output

a. In spite of the August and October raids on Schweinfurt, German production of bearings dropped only 5 per cent in the last quarter of 1943. However, output of medium bearings fell off by a third, chiefly because attacks had temporarily wiped out FAF production in this

GERMAN BEARINGS PRODUCTION UNDER ATTACK
1943 - 1944



SOURCE: SONDERRING KUGELLAGER

FIGURE 8

range.

86. Serious declines in output began to be evident in January, after the Erkner raid, followed by further drops as the Cannstatt, Schweinfurt, and Steyr attacks were felt in February, March and April. The index of total output dropped from 86 per cent of the pre-raid level in January to 49 per cent in April. Along with the direct efforts of these attacks, dispersal efforts were tying up productive capacity. The upturn occurred in May, when output from dispersal plants began to assume importance, and in the last quarter of 1944 the industry re-attained the pre-raid level, although production of VKF plants was still lagging.

87. However, the composition of bearings output was somewhat different from what it had been in the pre-raid period; there was a much larger proportion of extra-small bearings, which were produced in excess of need, especially by small firms. On the other hand, medium bearings, which had fallen to as low as 29 per cent in April, never recovered fully, and only two-thirds as many were produced in the latter part of 1944 as in mid-1943.

88. The data for bearings output during the period of attack may be summarized quarterly in the following index numbers:-

Second Quarter, 1943	100
Third Quarter, 1943	100
Fourth Quarter, 1943	95
First Quarter, 1944	73
Second Quarter, 1944	66
Third Quarter 1944	96
Fourth Quarter, 1944	104

89. In all, the production loss in anti-friction bearings may be computed at between two and three months' output at pre-raid levels. Production in 1944 was just 83 per cent of that in 1943, or a two months' loss; there was in addition a slight loss at the end of 1943 to be added and a considerable drop at the beginning of 1945.

Deliveries

90. The quarterly index for delivery of bearings to producers of end-items is somewhat different, due to the fact that bearings shipments were largely held up during the last quarter of 1943 to force the use of stocks held by equipment-making firms. In the first two quarters of 1944, the release of accumulated inventories of bearings manufactures served to augment current production, as reflected in the index below:

Second Quarter, 1943	100
Third Quarter, 1943	93

Table 19

Index of Production, German Anti-Friction Bearing Firms, July 1943-December 1944

All Bearings and Bearings in the Medium Size A Range *

Monthly Average 2nd Quarter 1943 = 100

All Bearings

Firms	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
VKF	103	95	100	89	96	89	63	47	30	31	47	64	65	70	82	89	77	75	70	43
FAG	101	92	94	88	102	95	97	80	68	40	46	70	77	77	90	90	97	86	85	60
Steyr	113	110	111	111	115	116	123	98	83	6	13	39	78	93	100	95	96	72	42	23
Müller	104	64	113	49	96	105	110	100	130	102	185	190	157	165	164	159	162	155	101	54
Kling	94	93	120	115	117	120	70	80	101	57	90	120	110	114	99	85	113	108	71	106
Small Firms	114	105	112	107	110	108	167	175	286	300	310	348	344	379	423	407	422	397	331	255
TOTAL	105	95	100	90	100	95	86	70	64	49	64	84	88	94	107	109	106	98	86	57

Bearings in Medium Size A Range

VKF	120	95	91	66	84	70	55	45	35	34	41	56	57	51	59	55	56	53		
FAG	91	68	83	45	39	60	71	71	61	22	23	32	52	68	78	63	68	64		
Steyr	120	115	103	103	86	66	115	81	66	0	4	38	60	85	97	88	91	80		
DKF	104	98	110	112	123	117	118	120	105	105	103	85	44	93	96	102	119	102		
Kling	125	92	97	60	71	100	62	90	83	86	93	100	63	93	66	81	108	81		
TOTAL	108	87	90	65	68	67	72	64	55	29	33	46	57	70	75	65	69	64		

* Source: Records of the Sonderring Waelzlager (Table 20) Figures do not include needle or other special bearings.

Table 20.

THE GERMAN ANTI-FRICTION BEARINGS INDUSTRY

Production of Finished Bearings

(Thousands of Pieces)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						1943						
VKF	3,920	3,833	4,627	4,040	4,614	4,034	4,385	4,020	4,240	3,767	4,077	3,744
FAG	1,904	1,987	2,250	1,972	2,211	2,115	2,126	1,924	1,984	1,820	2,137	1,983
Steyr	526	583	777	726	750	795	854	835	838	838	869	879
Müller	335	364	368	354	415	387	400	246	434	188	371	406
DKF	90	102	98	93	95	98	100	95	109	103	117	112
Kling	58	59	82	79	73	61	68	66	86	82	83	85
Small Firms	356	357	374	359	409	406	446	414	439	418	428	425
TOTAL	7,189	7,285	8,576	7,623	8,567	7,896	8,379	7,600	8,130	7,216	8,082	7,634
						1944						
VKF	2,657	2,008	1,280	1,299	1,995	2,716	2,786	2,944	3,458	3,799	3,258	3,201
FAG	2,041	1,687	1,428	844	975	1,460	1,618	1,621	1,896	1,897	2,042	1,799
Steyr	934	737	631	44	98	292	591	705	758	719	730	545
Müller	427	384	504	393	711	726	605	637	630	615	628	602
DKF	104	103	99	103	91	79	56	79	95	92	104	85
Kling	50	57	72	40	63	85	77	82	70	60	82	77
Small Firms	653	686	1,151	1,186	1,235	1,358	1,947	1,479	1,658	1,593	1,652	1,556
TOTAL	6,866	5,662	5,165	3,909	5,168	6,716	7,080	7,547	8,565	8,775	8,496	7,865
						1945						
VKF	2,967	1,803										
FAG	1,775	1,250										
Steyr	316	176										
Müller	393	210										
DKF	90	80										
Kling	50	75										
Small Firms	1,300	1,000										
TOTAL	6,891	4,594										

Source: Sonderring Waelzlager

Fourth Quarter, 1943	70
First Quarter, 1944	87
Second Quarter, 1944	82
Third Quarter, 1944	95
Fourth Quarter, 1944	101

91. Deliveries ran considerably below normal for over a year. However, there is no evidence that bearings shortages were ever serious enough to hold up the production of end-item equipment. There may have been individual instances of delay, since cases of hand-to-mouth use of bearings by aircraft, tank, and other equipment producers were frequently reported, but careful investigation failed to reveal specific instances of breakdowns in production lines due to lack of bearings. Nor is there any evidence that planned quotas for end-item equipment production were modified due to fears that sufficient anti-friction bearings would not be available. (Figure 9 - Index of Quarterly Production and Deliveries 1943 - 1944)

End-Item Production

92. The following index numbers of aircraft and tank production based on the second quarter of 1943 as 100 per cent, shows that production of this equipment remained high, during and after the period when bearings production was seriously reduced:-

Second Quarter, 1943	100	100
Third Quarter, 1943	106	105
Fourth Quarter 1943	94	113
First Quarter, 1944	108	128
Second Quarter 1944	150	153
Third Quarter, 1944	187	153
Fourth Quarter 1944	158	154

(Figure 10 - Monthly Indices of Production - Armaments and Bearings)

Needle Bearings

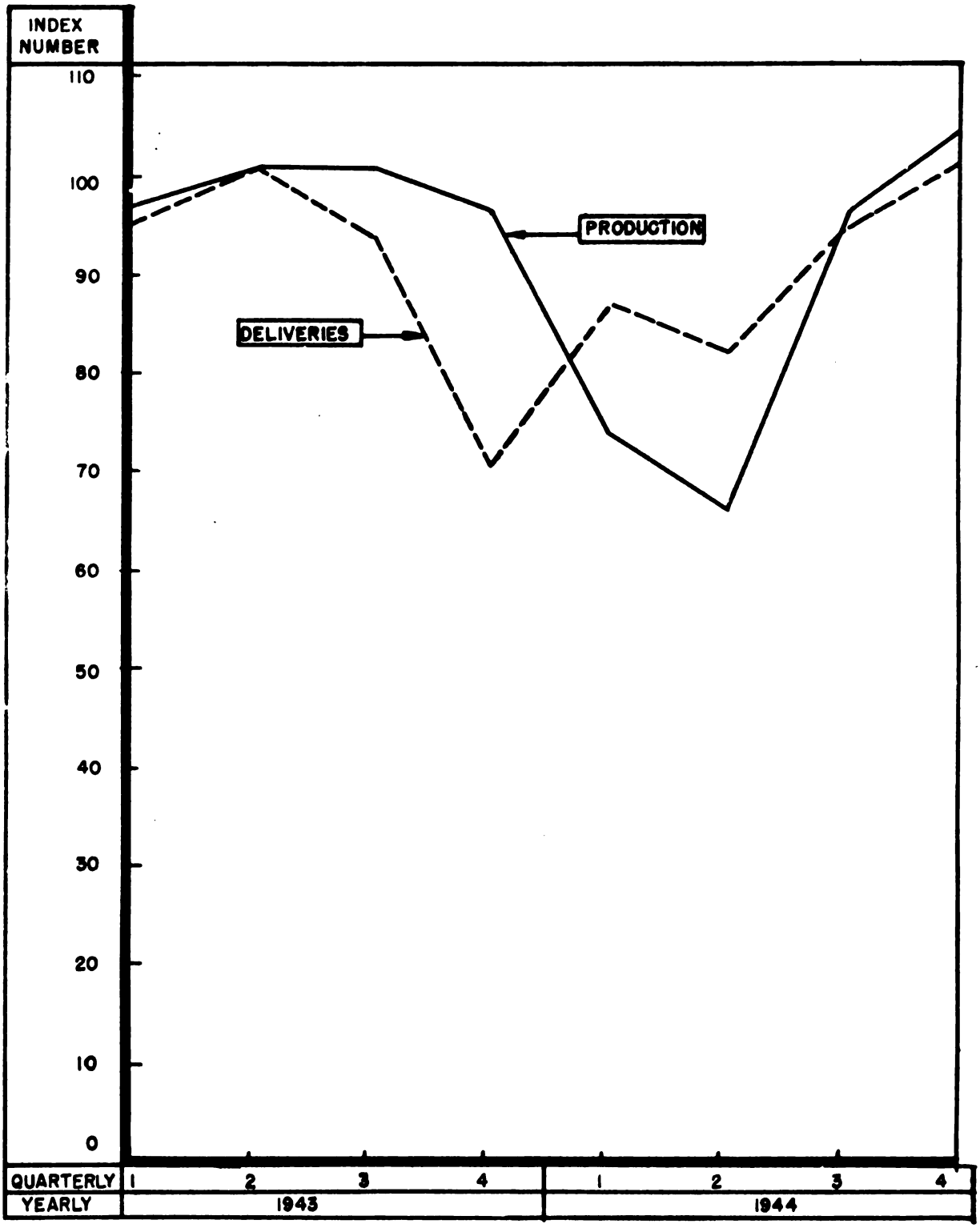
93. The production of needle bearings was not seriously affected by attacks. In fact, a cut in production quotas was ordered in mid-1943, due to the plentiful availability of the bearings. Production figures for these bearings are shown in Exhibit F.

D. Other Effects of Attacks

94. Among other effects on the bearings industry resulting from the raids were a marked increase in absenteeism, a high loss of working

INDEX OF QUARTERLY PRODUCTION AND DELIVERIES

GERMAN ANTI-FRICTION BEARING INDUSTRY



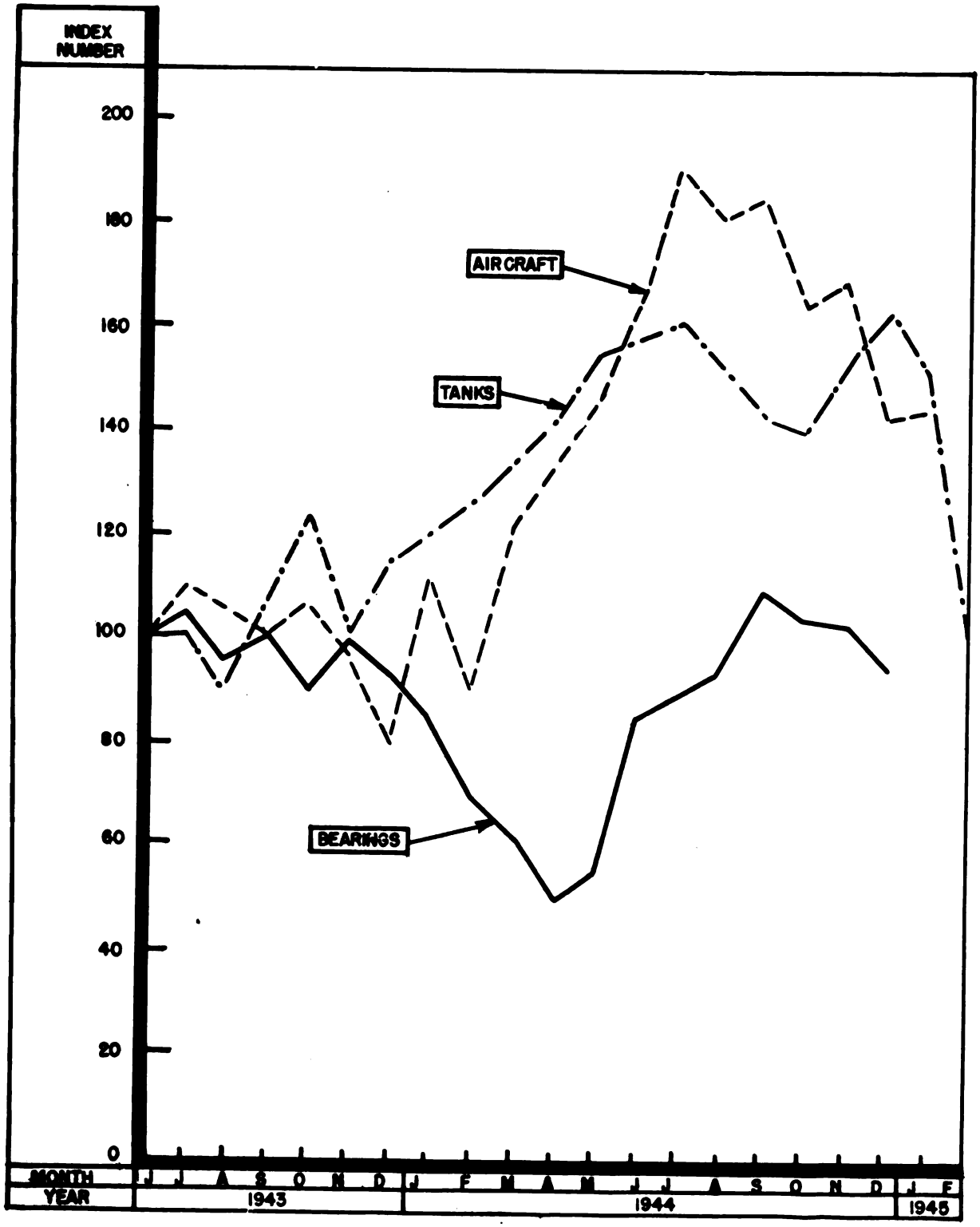
• NOTE:- APRIL-JUNE 1943 = 100

SOURCE:- SONDERRING WÖLZLAZER

FIGURE 9

MONTHLY INDICES OF PRODUCTION

ARMAMENTS & BEARINGS



AVERAGE MONTHLY PRODUCTION IN SECOND QT'R. 1945 = 100

SOURCE: USSBS A/C REPORTS
USSBS SPEER DOCUMENTS

FIGURE - 10

time due to alerts, and a decided decline in working efficiency and increase in costs.

Loss of Time Through Absenteeism and Alerts

95. The increase in absenteeism is strikingly illustrated in the following figures, which show monthly gross rates of absenteeism during 1943-1944 in the Kugelfischer plants at Schweinfurt and Ebelsbach, and in the dispersal plant at Schwartzenbach, where no bombings are believed to have taken place. Months in which raids on bearings plants occurred are starred.

TABLE 21

ABSENTEEISM RATES

Month	Schweinfurt	Ebelsbach	Schwartzenbach
January 1943	12.4	----	----
February	11.9	----	----
March	13.3	----	----
April	11.4	----	----
May	11.6	----	----
June	13.6	----	----
July	14.9	----	----
August	24.0*	----	----
September	17.7	----	----
October	19.1*	----	----
November	14.9	----	----
December	16.3	----	----
January 1944	15.4*	10.0*	----
February	17.3*	11.5	11.2
March	20.5*	13.0	8.0
April	20.6*	15.8	7.8
May	20.4	13.1	11.3
June	17.9	11.5	10.6
July	18.4*	13.7*	13.4
August	18.4	18.9	10.8
September	13.0	12.7	7.4
October	12.7	13.2	7.0
November	12.4	9.1	6.6
December	13.3	10.6	6.3

(Source: Records of Kugelfischer Firm)

96. The data show a clearly defined increase in absenteeism during and after raid periods in Schweinfurt and Ebelsbach. In comparison,

the rate at Schwartzenbach, which had no raids, was much lower than that of either of the other two plants.

97. The following figures show monthly the number of hours lost in Schweinfurt plants due to air alerts during 1943 and 1944:-

TABLE 22

HOURS LOST DURING ALERTS

Month	1943	1944
January	---	10.9
February	1.8	6.6
March	3.2	33.3
April	4.8	30.0
May	1.8	15.1
June	.7	2.4
July	1.9	14.2
August	15.3	18.3
September	7.1	6.1
October	15.5	39.3
November	14.4	18.5
December	6.2	20.9

(Source: VKF Records)

Increased Costs

98. Though absenteeism and loss of time due to alerts and air attacks were secondary factors in the loss of production in the bearings industry, the underlying reasons for decline in working efficiency were the increased production costs through dispersal. In fact, though output reached the pre-raid level in October 1944, with 8.8 million bearings produced, slightly more than the 8.4 million of July 1943, many more workers were needed as well as more machines and more floor space. To produce the number of bearings equivalent to the pre-raid level 13,000 more workers were needed; 8,000 more machines and 322,800 sq ft more floor space had to be employed. Even then, production was not equivalent, because the composition of output included many more small, easier-to-make bearings. (Figure 11 - Employment and value of output delivered 1939-1944.)

99. A more realistic picture is provided by the following figures, which show the changes in value produced per worker in the German anti-friction bearings industry 1943-1944: (as computed from figures on total employment and value of products delivered - Exhibits E & H.)

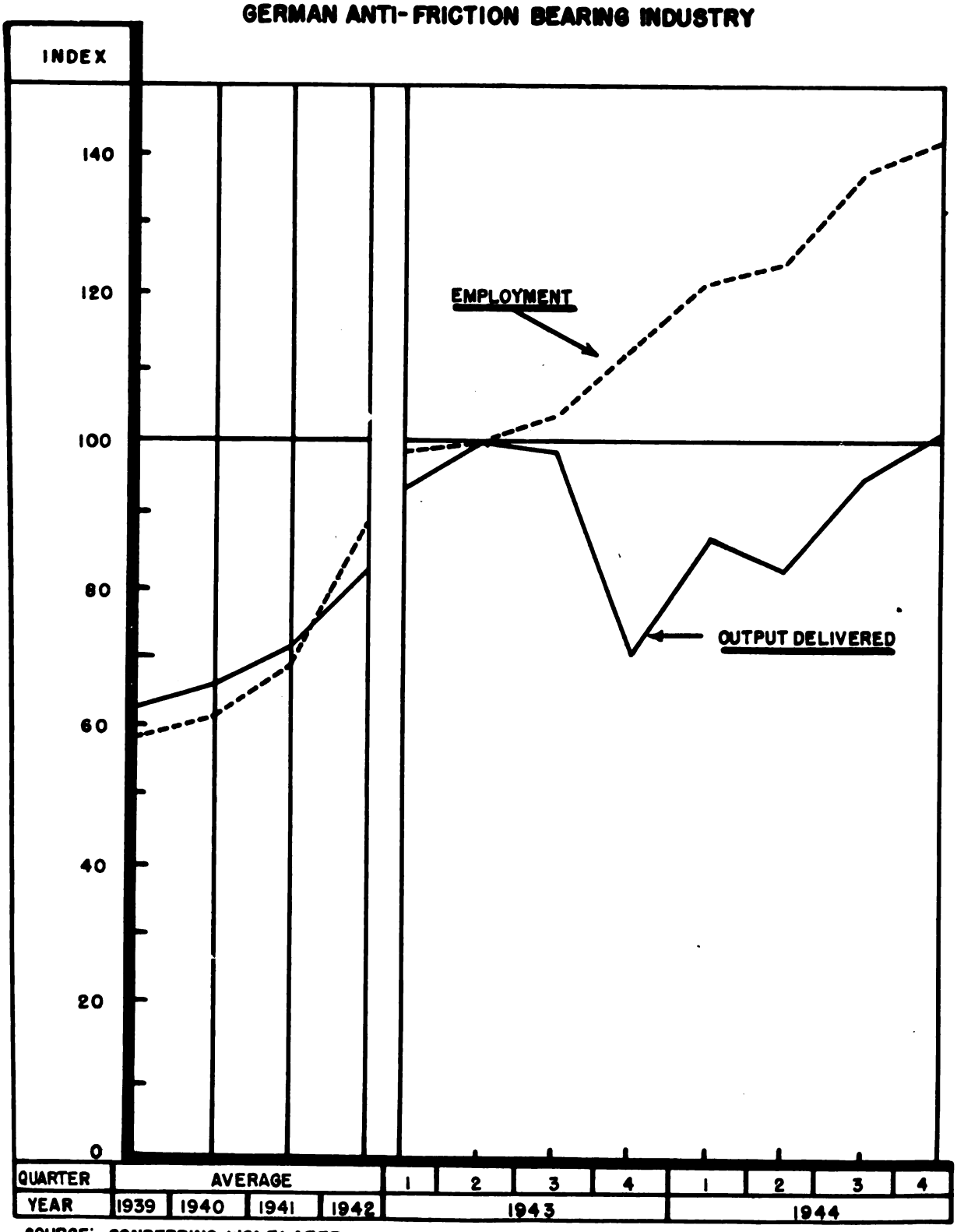
First Quarter 1943	RM-1,995
Second Quarter 1943	2,069
Third Quarter 1943	1,839
Fourth Quarter 1943)	
First Quarter 1944)	1,415
Second Quarter 1944	1,349
Third Quarter 1944	1,416
Fourth Quarter 1944	1,447

100. Between the pre-raid period and the fall of 1944, when the bearings industry had achieved recovery, productivity per worker dropped roughly by one quarter.

101. In spite of the recovery achieved by the anti-friction bearings industry in October, and although bomber attacks on bearings targets ended around this time, the industry was unable to maintain its position when the winter set in. In December and succeeding months the all-out offensive against the German transportation system affected production levels, preventing deliveries of steel and other raw materials and hindering the assembly of components produced at dispersal plants situated at distant locations. As a result, a steady decline in production set in, despite the fact that potential capacity remained high (Table 19)

INDEX OF EMPLOYMENT & VALUE OF OUTPUT DELIVERED

GERMAN ANTI-FRICTION BEARING INDUSTRY

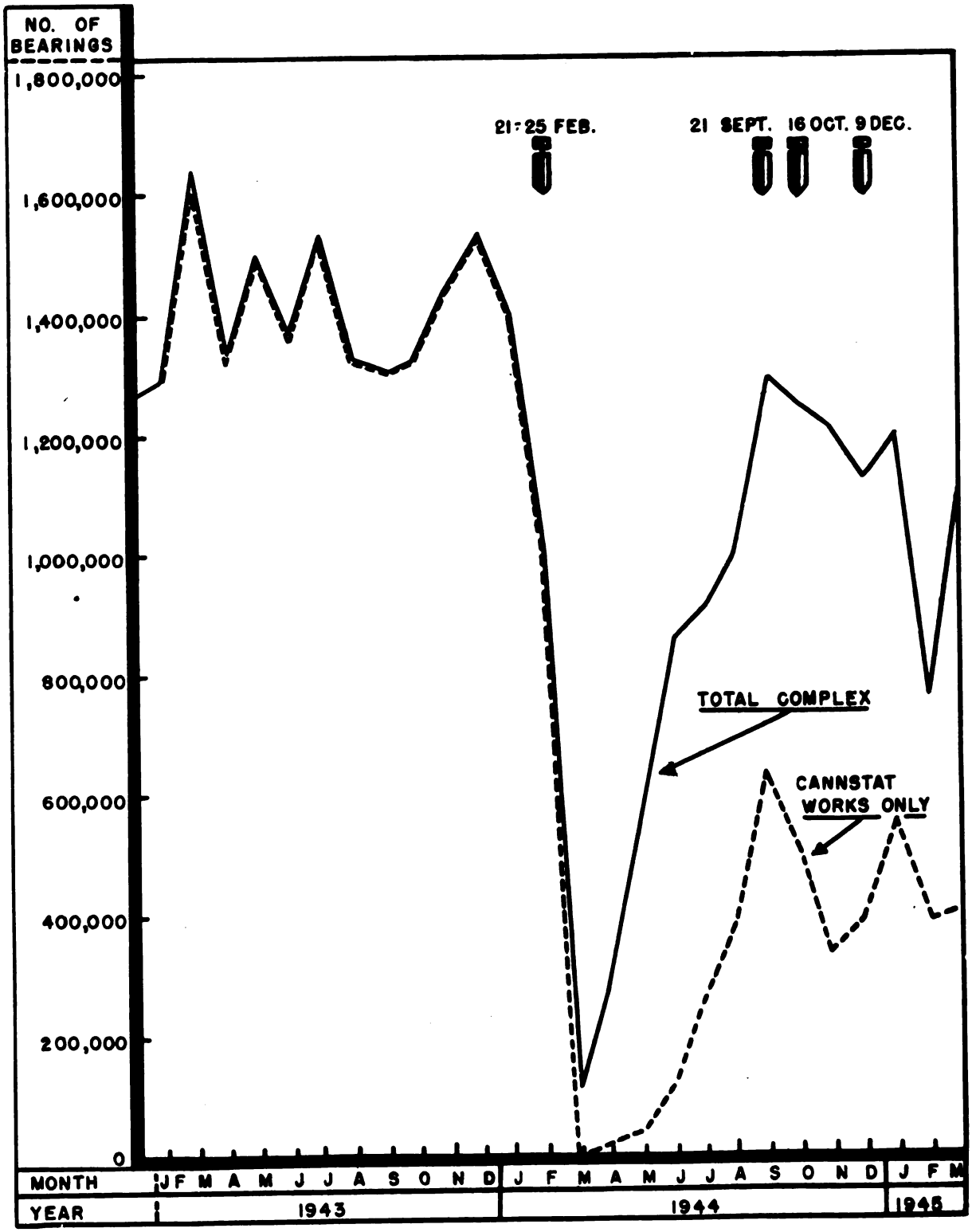


SOURCE: SONDERRING WOLZLAZER

2ND QUARTER 1943 = 100

PRODUCTION OF FINISHED BEARINGS

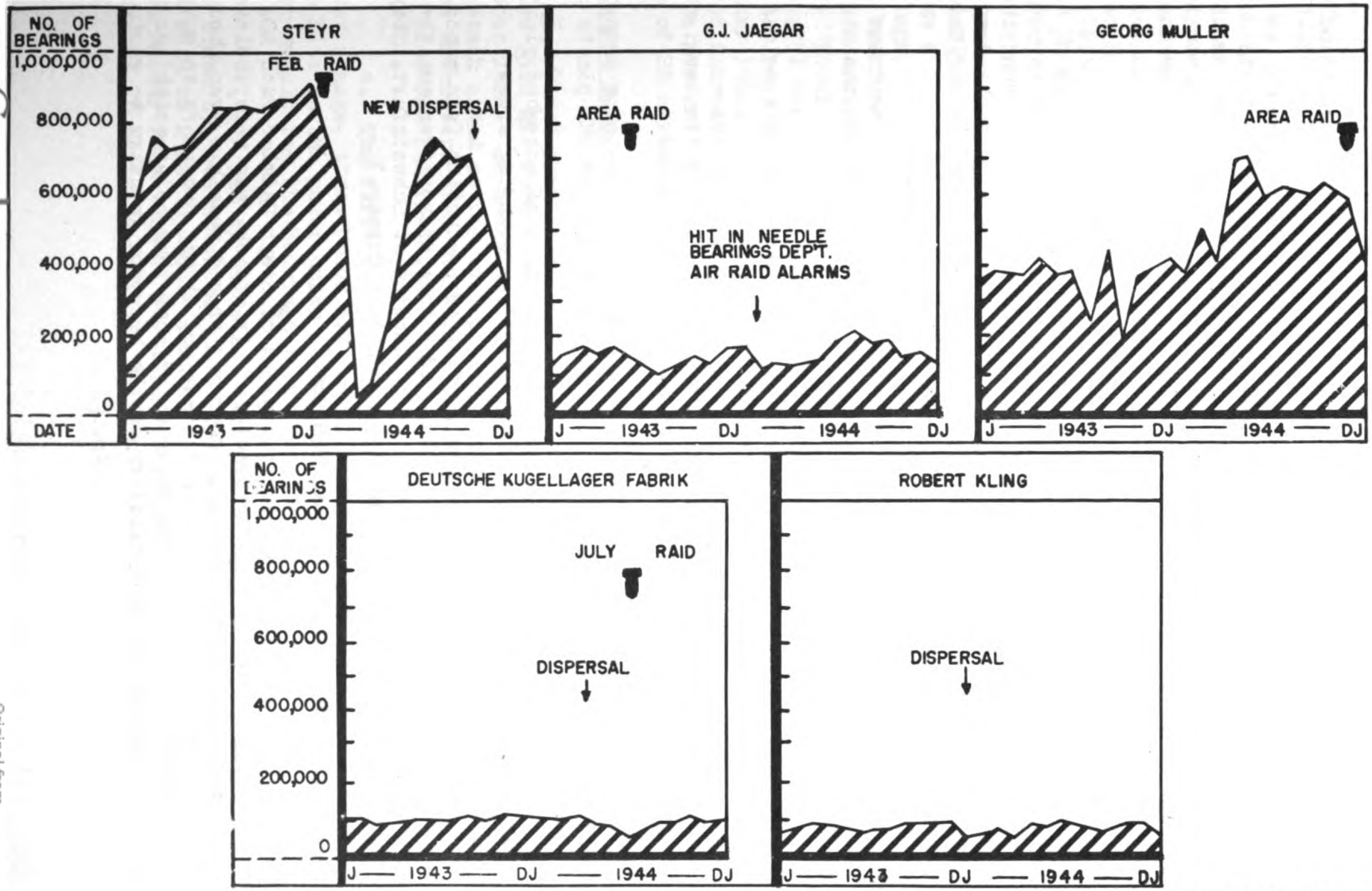
VKF BAD CANNSTATT COMPLEX



SOURCE: PLANT RECORDS

FIGURE 12

ANTI-FRICTION BEARINGS PRODUCTION OF INDIVIDUAL PLANTS



SOURCE: PLANT RECORDS

CHAPTER FOUR DIRECT AND INDIRECT EFFECTS OF BOMBING ON PLANTS

1. The individual plants furnish the most clear-cut tests of what has been achieved by bombing, both directly and indirectly. Effects of direct attacks need to be studied at the plant affected as well as in the overall industry statistics. Moreover, the indirect effects on the whole industry, such as loss of working time through absenteeism or effort diverted to dispersal and bombproofing, are different from the sum of the direct effects of attacks on specific targets. These indirect effects are evident at unbombed plants.

2. This chapter, therefore, supplements the earlier study of the total effect of the raids with brief analyses of the reactions of the other major plants. Complete studies of the various plants are not attempted; instead, each section is focussed on the unique contribution that the individual plant can make to our understanding of the German anti-friction bearings industry under attack. The general conclusions can be briefly summarized.

a. It was possible to knock out production in a bearings plant completely -- Ebelsbach, Steyr, Erkner, Stuttgart are the evidence.

b. Production was always restored at a bombed site unless there was a decision by the Germans to disperse.

c. Dispersal proved quite possible in a short time even when there were no prepared sites, as the Steyr experience shows.

d. Dispersal could only be carried out at cost of a drop in production, as the experience of the unharmed Kling and DKF plants show.

e. Area raids interfered with production of unbombed plants, but only when of shattering intensity on the surrounding area.

f. The steady or increasing flow of production from minor plants, such as Jaeger, Muller, DKF, and Kling, helped overcome the effects of raids on major centers of production at Schweinfurt, Steyr, Stuttgart, and Berlin. (Figure 13, Production Curves.)

A. Steyr - The Crucial Test of Dispersal

3. The anti-friction bearings plant of Steyr-Daimler-Puch AG, though extensively damaged by precision air attack, was nevertheless able to recover fairly rapidly. Recovery proved possible even though prepared dispersal sites were not ready and it was necessary to move to temporary buildings. The Steyr experience thus helps establish the extreme mobility and adaptability of the bearings industry to various

conditions of production.

The Plant

4. Steyr was the third largest producer of anti-friction bearings in Axis Europe, the largest manufacturer independent of the Schweinfurt complexes. It was an expansion of the bearings department of the Steyr-Daimler - Puch auto and aero engine plant, supported by the resources of the Hermann Goering concern after the annexation of Austria by Germany. Located in Steyr, Austria, the plant was a very modern straight-line production factory, constructed in 1941, covering approximately 500,000 sq ft of floor space, and containing about 2,000 machine tools. (Exhibit M for plant layout.) The labor force, constantly increasing, stood at 4,474 in July 1943 and at a peak of 6,153 in December 1944. About 1,000 different types of ball, cylindrical and tapered roller bearings were manufactured, from the smallest size of 5-mm bore up to a few large ones of 500-mm outer diameter; main effort was concentrated on the medium sizes. Included were the extremely important propellor thrust bearings, of which Steyr claimed to furnish 70 per cent, and the Maybach tank bearings. With the completion of the ball plant in 1941 and cylinder-roller department in 1943, Steyr became a complete production unit. Total output for 1943 was 9,280,365 bearings and for 1944 6,784,251 bearings, approximately 10-12 per cent of the industry's total. Peak monthly production -- 934,273 bearings -- was reached in January 1944. The rise in rate of output had been steady, and a continued increase was planned; the goal for the end of 1944, which had been a production rate of 15 million bearings yearly, was raised to a rate of 20 million bearings yearly just before the first raids.

Raids and Damage

5. Three precision raids were directed against the Steyr plant by the 15th Air Force, on 23/24 February 1944, 2 April 1944 and 16 October 1944. In addition, the plant was hit on 24 February 1944 by an attack aimed at the main plant of Steyr-Daimler-Puch AG, located three kilometers from the bearings plant. (Exhibit M for combined bomb plot for all raids.)

a. The first attacks, on 23/24 February 1944, caused little direct damage, three bombs hit the grinding department; more important were hits on the power units at the main works, which interrupted the power supply for the bearings plant for two weeks.

b. Warned by these attacks, preliminary plans for dispersal were drawn up, but no actual moves had been made at the time of the next raid on 2 April 1944. Bombing was accurate and destruction extensive, mainly from blast. Plant officials estimated factory building damage at 70 per cent. Of the 2,000 machines, 200 were totally

destroyed, mainly in the grinding department (Bldg 3) and in the ball and roller works (Bldg 6.) Another five or six hundred were damaged, but repairable. About 50 per cent of the bearings in process were also destroyed, an average of two months' production of stocks of components was damaged, and utilities were knocked out for a month.

Recuperation

6. At the time of the April attack, preliminary plans contemplated the eventual establishment of two complete underground factories at Linz and at Melk. Neither was ready at the time, however; Linz consisted simply of huge underground beer and wine cellars, and Melk was little more than a mountainside. While they were hastily being prepared, various temporary above-ground sites were pressed into service to house manufacture of retainers, rings, and balls, and for assembly. Only the hardening department and the forge, relatively undamaged, were retained at Steyr, where they resumed operation once power had been restored. A plant at Letten, already in operation, was also available for immediate use and might be expanded. (Table 23)

7. As Linz became ready in May and Melk in November 1944, the machines from temporary sites were shifted to these underground factories. There they were completely insulated from air-attack. (Exhibit N for photographs of entrances to Linz.)

8. The April raid and the decision for immediate dispersal kept production at an extremely low level for two months, most of the April and May output coming from Letten (Table 20 for 1943-1944 monthly production.) Thereafter, recovery was fairly rapid, and September production of 757,560 bearings, the peak post-raid output, was approximately 75 per cent of the January figure. This development was possible largely because almost 65 per cent of the machines were not damaged in the air raids, new machines previously ordered as part of a general expansion program were received, and high priorities were obtained for building materials and repair of damaged machines from General Commissioner Kessler.

Production Loss

9. The intermingled factors of dispersal and damaged and destroyed equipment caused an accumulated four and one-half months production loss by the end of the year, assuming that the production of January 1944 could have been maintained. It is safe to conclude, however, that dispersal and the cessation of production while machinery was being transferred from one place to another was the immediate cause of the decrease in production. After the post-raid peak had been reached in September, production fell off again, largely because machinery was

TABLE 23

DISPERSAL PLANTS OF STEYR-DAIMLER-PUCH

Plant Location	Date Established	Products Made	Disposition of Machines
Temporary Above Ground Sites			
Letten	December 1943	Retainers, Roller Bearings	Moved to Linz, May 1944
	April 1944	Hardening turning assembly	
Rosenau (Lahrndorf)	April 1944	Assembly	Moved to Melk February 1945
Ternberg	April 1944	Ring turning	To Linz and Melk December 1944
Rottenmann	September 1944	Balls	To be moved Linz
Ried	Before April 1944	Storage finished bearings	
Sierninghofen	-	Raw material stores	
Permanent Underground Sites			
Linz	May 1944	1,000 machines for making roller bearings, retainers and rings for balls, pressing of balls	
Melk	November 1944	600 machines for ring production and ball-bearing assembly	

(Source: Plant Records and Interrogation.)

once more in the process of being moved from the temporary plants to Melk. Later, when the Russian armies threatened to overrun Melk, plant officials attempted to transfer their machinery back to Steyr and Linz, with further confusion and production loss.

10. Additional indirect bombing effects contributing to the lag in recovery to pre-raid levels included the difficulties of interplant transportation, which became increasingly serious early in 1945, and power shortages due to area raids at individual plants such as Linz, which was shut down for eight days in December because of lack of current.

B. Dispersal to Prepared Sites: VKF Bad Cannstatt

Stuttgart Introduction:

11. The recovery effort of the VKF plant at Bad Cannstatt, a suburb of Stuttgart, had several interesting aspects. The decision to recuperate in dispersal plants rather than in the damaged works, logical in view of the already advanced dispersal program, failed to produce a shorter recuperation period than did the Steyr program, where before the attack dispersal was no more than a plan. The delay at Stuttgart, it appeared, resulted from three factors that hampered recovery. Most important was the unusually heavy damage to vital equipment, especially transformers and hardening furnaces. Next, the double attack, in which an effective area raid of 21 February 1944 was followed up by an equally effective precision attack on 25 February, resulted in more total damage than if there had been a longer time interval between the attacks. Lastly, a series of area raids on Stuttgart in July 1944 interfered noticeably with the factory's activities.

The Plant and Its Importance in Enemy Economy

12. The Vereinigte Kugellager Fabrik AG of Bad Cannstatt, Stuttgart, was the fourth largest German producer of anti-friction bearings, accounting in number of pieces for 18 per cent of total German output in 1943 and 13 per cent in 1944. About 10 per cent of production was in the smaller sizes up to 62-mm bore. In addition to these standard types of ball and roller bearings, the firm made a substantial number of special bearings. Balls were not manufactured in Cannstatt but were secured from Schweinfurt.

13. The main plant at Bad Cannstatt consisted of 15 buildings, all of standard commercial construction with the exception of two new multi-story buildings which were of heavy concrete and reinforced steel. The 2,5,605 sq ft (five acres) of factory floor space available were concentrated in an area of 8.2 acres and of these, 107,000 sq feet or

approximately 50 per cent had been destroyed by the combined bomber offensive up to January 1945. (Exhibit Q plant layout for detailed picture of buildings and processes).

14. In addition to the main plant, VKF established 13 dispersal plants in the vicinity of Bad Cannstatt beginning in July 1942.

15. This program was already well under way at the time of the February 1945 air attacks, with six dispersal points in production and was practically completed by July 1944 (Table 24 for list of dispersal points and products.) The general dispersal pattern of the industry, by departments, was followed.

Employees

16. While the number of employees at the whole complex of VKF Cannstatt was steadily rising during 1943 and 1944, the overall increase being 18 per cent, (from 3,690 in January 1943 to 4,358 in February 1945), the labor force at the Cannstatt works decreased rapidly, falling from 3,407 or 81 per cent of the total force in March 1944 to 2,228 or 51 per cent in February 1945. However, in evaluating the productive importance of the Cannstatt works in relation to that of the dispersal plants, it should be borne in mind that the Cannstatt figures included an office force of 500.

The Attacks and the Physical Damage

17. VKF Cannstatt was the target of one precision attack and was also hit by six area attacks between 16 April 1943 and 9 December 1944. (Exhibit B1 -- List of Attacks and Number of Hits.)

18. The first serious air blow was struck at the plant on the 21 February 1944 raid, when 536 heavy bombers of RAF Bomber Command raided the Stuttgart area and dropped 1045.5 tons of HEs and 638.4 tons of IBs on the city. Two HEs and 59 IBs fell in the plant area, and four HEs and 46 IBs hit the buildings as follows: (Exhibit Q and Photos 102-111)

a. Grinding Department (Bldg IV) Two HEs - Out of 130 grinding machines, 10 were totally destroyed, and 20 slightly damaged by blast, fragmentation, falling debris, and small fires. The remaining machines could have resumed operation in three to four weeks.

b. Hardening Department (Bldg II) One HE destroyed about 30 per cent of the building and some equipment by blast and fragmentation.

c. Transformers (Bldg XIV) hit by one HE; four transformers were destroyed.

d. Turning Department (Bldg III) Hit by 12 IBs causing total destruction by fire of 10 automatics and slight damage to 34 automatics.

e. Fire raged in the plant area for six to eight hours after the attack, causing destruction of millions of components in various stages of process, of 20,000 finished bearings in the shipping department (Bldg VIII), with building damage to grinding department (Bldg 1 A) and barracks, all hit by IBs.

19. Hardly had the fires been extinguished from the RAF attack of 21 February when the plant was hit again on 25 February 1944. This time, VKF was the target of precision attack by 55 B-17s of the Eighth AF which dropped 138 1,000-lb HEs, 28 500-lb HEs, and 79 100-lb IBs, on the plant.

20. One HE and two IBs hit the plant area and nine HEs and three IBs hit the buildings, causing damage as follows:

a. Hardening Department (Bldg II) Approximately 50 per cent of hardening and tempering furnaces, quenching devices, and exhaustion equipment was badly damaged or destroyed.

b. Grinding Department (Bldg 1a) One-third of roof and floor space destroyed; out of 140 machines, 20 were damaged but repairable.

c. High Precision Grinding and Assembly (Bldg I) Three grinders destroyed by blast and fire and 10 slightly damaged; 50 measuring machines in cellar also destroyed.

d. Miscellaneous damage included destruction of raw materials, office building (Bldg I) by fire, and destruction of water and gas mains.

21. The fact that these two raids took place in such rapid succession made overall damage much more extensive than if there had been a longer interval between them. The fires caused by the RAF attack made the buildings and damaged machinery extremely vulnerable to air attack, while debris clearance and movement of damaged and destroyed machinery and equipment had only just begun at the time of the Eighth AF attack.

Other raids caused only minor damage (see list of raids and bomb plot, Exhibit Q.)

Production Loss

22. Largely as a result of the air attacks of 21 and 25 February 1944, production at VKF Cannstatt and its dispersal plant fell from a

TABLE 24

VKF BAD CANNSTATT DISPERSAL PLANTS

Plant Location	Sq Ft Floor Space	Machines in 1945	Former Owner	Started Dispersal	Started Production	Product Made
Stuttgart	10,539	13	I. Schmidt Textile Co	July 42	Sept 42	Needle Roller Bearings
Marbach	3,745	14	H. Buhrer Machine Shop	Sept 42	Nov 42	Brass Tubing Retainers
Ebingen	5,350	18	Groz Sohne Machine Shop	Sept 42	Nov 42	Needle Roller
Rommelsbach	41,730	68	U. Gminder	Feb 43	Sept 43	Cylinder Roller Bearings
Reutlingen	45,475	115	U. Gminder	Oct 43	Jan 44	Ball Brng complete. Solid retainers for cyl roller bearings.
Neckartenz-lingen	41,730	119	U. Gminder	Nov 43	Jan 44	Ball Brg Grinding & assembly
Riederich	12,840	82	Winkler & Sohne	Jan 44	Mar 44	Special retainers & aluminum retainers
Neunstadtt	1,712	7	Otto Neu-meister	Mar 44	Apr 44	Automatics Turning
Kirchheim	14,445	49	I. Batten-schlag	Mar 44	Jun 44	High precision Ball Brgs
Metzingen	4,922	26	Hugo Boss	Mar 44	Jul 44	Turning Races
Metzingen	54,570	114	Eugene Ott & Sohne	Oct 44	Feb 45	Grinding Races & Assembly
Stuttgart	12,840	90 (x)	Auto Schott	Jan 45	Mar 45	Tool Rooms Textile spindlers
	249,898	715				
Neckar-zimmeren	645,800(z)	50	VKF (Sch-weinfurt)	Feb 45	(y)	Ball & Roller Bearings
Neckar-zimmeren	25	50	VKF (Sch-weinfurt)	Sep 44	Oct 44	Cylindrical Rolls

(x) - these machines did not belong to VKF but were owned by Auto Schott.
(y) - these machines did not arrive at cave; lost in transport.
(z) - this was total area planned for the Neckar-aimmeren cave, the VKF planned underground plant.
(Source: Plant Reports)

total of 16,723,170 bearings in 1943 to 10,811,738 in 1944, a decrease of 35 per cent. Destruction of the hardening furnaces and transformers was the main factor causing a complete stoppage at the Canstatt works from the time of the attacks until June when reduced production began. Output which had reached a monthly average of 1,399,000 for the last six months of 1943 and had maintained itself during January, 1944 fell off to 890,000 in February and 93,000 in March. It was not until September that production was almost fully restored to pre-raid levels, an estimated loss of four months' production.

23. A further direct result of the attacks was the large number of labor hours lost by VKF due to repairs, reconstruction, dispersal, and absenteeism, as the following table indicates:

TABLE 25

LOSS OF PRODUCTIVE HOURS

A	B	C	D	E
1944	Available Hours	Reconstruction	Absenteeism	% Absenteeism
Feb	564,000	50,000	187,000	33%
Mar	722,000	240,000	125,000	17%
Apr	725,000	178,000	114,000	16%
May	662,000	91,000	109,000	16%
Jun	693,000	81,000	96,000	14%
Jul	655,000	27,000	127,000	19%
Aug	590,000	22,000	150,000	25%
Sep	695,000	30,000	164,000	24%
Oct	712,000	31,000	143,000	20%
Nov	830,000	21,000	133,000	16%
Dec	694,000	41,000	126,000	18%

(Source: Plant Records)

24. In addition to the diversion of the full-time labor force of approximately 1,000 of the plants' employees in March and over 700 in April to the work of reconstruction and setting up the dispersal plants, VKF secured the services of some 500 men from the Todt organization to help in clearing the debris. Hours spent on reconstruction and repair did not drop off substantially until July.

25. One hundred and eighty seven thousand hours, or 33 per cent of hours available, were lost in February due to sickness, leaves, air-raid alarms, and damage to employees' homes; the largest part being made up of leave which the employees were forced to take following the closing down of the plant after the raids. Absenteeism declined

steadily thereafter until July, when it began to rise again following the six area raids on Stuttgart in the latter half of that month, and reaches its peak in September, largely as a result of the increase in hours lost due to air-raid alarms. Although absenteeism averaged 18 per cent during 1944 (not including February) and undoubtedly affected potential production, its high points did not coincide with production lows, except immediately after the February raids.

26. Raw material shortages and transportation difficulties did not hamper VKF seriously until the beginning of 1945 when deliveries could not be made. In January 1945, electric power was shut down for 10 days, causing a complete stoppage of production and was not restored to normal requirements until 3 March. This power shortage is reflected in the substantial drop in production in February when output fell to 61.3 per cent of the January total.

Recuperation

27. A well established dispersal program was already in existence at VKF in February 1944 and the Cannstatt works were assuming an increasingly unimportant position in the output of the Cannstatt combine. Thus, while the double attack caused severe production losses, a greater total loss would undoubtedly have resulted had these attacks taken place six months previously when these dispersal plants were not yet in full operation. This is strikingly revealed by an analysis of February production statistics, which show that while 97 per cent of final assembly took place in Cannstatt, a very large proportion of components was made at dispersal plants.

TABLE 26

PERCENTAGE OF PRODUCTION OF FINISHED BEARINGS AND COMPONENTS AT CANNSTATT WORKS

	February 1944		December 1944	
	Total Combined Production	% at Cannstatt	Total Combined Production	% at Cannstatt
Final Assembly	861,164	90	1,111,596	33
Cylinder Rollers	7,159,974	51	6,774,132	13
Needles	21,157,640	29	15,252,390	1
Retainers Magneto type Ball Bearings	396,260	0	360,954	0
Solid Retainers, Ball Bearings	91,063	100	25,848	74
Sheet Metal Retainers, Other Ball Bearings	798,077	50	943,560	0
Sheet Metal Retainers, Roller Bearings	105,161	100	125,669	6
Solid Retainers, Roller Bearings	92,017	67	100,704	37

(Source: VKF Cannstatt Records)

28. A comparison of February with December 1944 figures shows how complete the dispersal was. No attempt was made to restore production at Cannstatt but efforts at recuperation were concentrated on expanding the dispersal program. After February, the Cannstatt plant never again presented the target it had been before the raids because at no time thereafter did its output exceed one - third of the combine's total.

29. That production did not reattain the peak of 1943 can be attributed partly to the inefficiencies inherent in a dispersed production as compared to a concentrated production.

C. Recovery after an Obliteration Attack: Ebelsbach

30. The Kugelfischer plant at Ebelsbach was more completely devasted by a single raid than any other German plant, and for that reason the story of that raid and its effects is retold here. The summary is based in large part on Physical Damage Report 18. Ebelsbach's place in the industry is described fully in Chapters III and VI; here it will suffice to say that it was a dispersal plant from Kugelfischer, Schweinfurt, making nearly all of Kugelfischer's balls and about one-third of the industry's total needs for balls.

The Plant

31. The plant was located on the Main River between Schweinfurt and Bamberg. Its site spread over 39 acres but the buildings, about 204,000 sq ft, covered only 15 per cent of the site and were compactly grouped together in about 10 acres of the site. The buildings were all one store; half the floor space was constructed with steel-frame masonry load-bearing walls, another quarter with prefabricated concrete frame and curtain walls, and the bulk of the rest with wood-frame.

Attacks

32. The first attack, by 54 B-17s on 19 July 1944, was ineffective despite the absence of flak or fighters. A heavy smoke screen obscured the target, and the bombs fell mainly in adjoining fields.

33. A repeat attack on 21 July again met no opposition, and wind blew away the smoke screen permitting effective bombing. Ninety-two HEs - almost a fifth of the 490 500-lb GPs dropped- hit in the target area, with a density of 2.4 per acre. The buildings received 38 hits or near misses from HEs. Data on incendiaries is less reliable but the plant officials estimated hits at 10 100-lb bombs and about 700 small 4-lb bombs from clusters.

Damage

34. Because of the building construction most of the damage came from blast which caused about 60 per cent, and from fragmentation, which caused 25 per cent. Almost 40 per cent of the plant was completely destroyed, and destruction plus structural damage came to 67 per cent of the buildings. Only 15 per cent of the floor space was unaffected.

35. Damage to contents was less extensive. Of machine tools 12 per cent were destroyed and another 28 damaged; damage to other plant installations was over 60 per cent. Considerable stocks of semi-finished balls (214 tons) suffered from exposure and had to be salvaged or reworked and 27 tons of finished balls - a weeks output - were lost.

Hundreds of tons of raw material were damaged, but not irrecoverably.

Recovery

36. The repeated raids on Ebelsbach persuaded the Germans that reconstruction there would be foolhardy. Recovery was hence centered at Ebern, where preliminary work had already been begun, and at Gleisenau. The operations continuing at Ebelsbach (to take advantage of facilities such as heat treatment furnaces that still remained) were carefully concealed in cellars under the rubble and camouflaged to hide the activities. About a fifth of the destroyed floor space was restored in the next two months, at an expenditure of over 400,000 man hours. By three months, half the damaged installations and nine-tenths of the damaged machine tools were again working. The bulk of the repaired tools were sent to Ebern. Production at Ebelsbach, nil in August, reached a figure of 53 tons in October. The operations carried out were only the simplest, however, and the importance of the plant would be overrated by a literal interpretation of the figure. Production at Ebern and Gleisenau, which reached 62 tons in January 1945, included the balls of higher quality and precision.

Comment

37. Two implications stand out from a contrast of this raid with other raids on the industry.

a. The attack of 21 July which devastated the plant dropped only half as much tonnage as the October 1943 raid on Schweinfurt. The target at Ebelsbach, however, was an undefended plant of about six acres of buildings grouped in an area of about 10 acres; while the heavily defended Schweinfurt target had three separate sectors with a total area of 41 acres on sites totalling 81 acres. Thus, the double tonnage of the October 1943 Schweinfurt raids fell on a target between seven and eight times as large as Ebelsbach despite fierce fighter and flak opposition and the density of hits was naturally much lower. To achieve results like those at Ebelsbach the Schweinfurt attacks would have required along with the October accuracy a tonnage of bombs three to four times as great as was actually dropped at that time. Such a conclusion, though the figures cannot of course be accepted as precise or rigidly proved, is supported by the general body of the attack and damage data.

b. Despite the devastation, the plant was able to recover in three months to a half of the pre-raid level of production. The usual pattern (combining dispersal, repair of damaged equipment, and restoration of untouched facilities) was followed. The success of repair and replacement of machine tools-- 90 per cent in three months-- is particularly striking. The contrast with the post-raid history of SRO,

Annecy, is instructive. Similar extensive damage tothe French plant kept it out of production till the end of the war. Though the dispersal site was selected, material and machines were not forthcoming and both management and workers were apathetic or actively obstructive. At Ebelsbach, full energies, ample material and abundant machine-building and repair facilities enabled rapid recovery. The clear conclusion is that, however devastated a bearings plant is, its return to operation is possible if a relatively slight part of the resources of the economy are funnelled into it and if the spirit of the labor and managerial force is undiminished.

D. I. G. & J. Jaeger, Wuppertal

38. The Wuppertal subsidiary of Kugelfischer, G. & J. Jaeger GmbH was a relatively unscathed plant whose steady output helped support the German industry. The steady rise in the production curve is interrupted only twice, first by the effects of an RAF area raid in June 1943, and later by a bomb in the needle bearings department in early February 1944. Recovery was made from both these attacks, andthe wartime high in piece production was reached in August 1944.

The Plant and Product.

39. The Jaeger plant is located in the southwest section of the city of Wuppertal, in the Elberfeld suburb, approximately two miles from the center of town. The plant is composed of 15 buildings in an area of about 60 acres. The old part of the plant, originally designed for steel and cast-iron foundry use but converted into a bearings plant about 1926, now houses maintenance and special-design bearings departments with about five acres of floor space. The other operations are carried on in new buildings well-lighted, ventilated, heated, conveyorized, and in all respects the most modern anti-friction bearings plant in Germany. Power and equipment were available for a production considerably above that actually achieved.

40. The force was protected by heavy blast walls two meters thick and 10 meters high. After the Schweinfurt raids, the Kugelfischer management took the additional precaution of having all productive equipment which had been operating on the main floor of Bldg 1 moved to the cellar. The main factory floor was henceforth used only for storage; 100,000 sq ft of productive floor space were given up. The only dispersal was the shipping of some of the machinery for making large bearings to Gundelsheim, below Nuremberg, a Kugelfischer dispersal point; this was done in the summer of 1944.

41. G. & J. Jaeger manufactured anti-friction bearings of all types, but concentrated on special constructions of large sizes, such as railroad axels, bearings, and housing, submarine propeller-shaft bearings,

rolling mill bearings, gun turret bearings, and other heavy applications. The output of 1,788,511 bearings in 1943 was about 1.9 per cent of German production, and increased to 2,020,410 in 1944, or 2.5 per cent. The relative importance of the plant is somewhat greater, however, since 50 per cent of the bearings produced fell in the critical medium size range.

42. The labor force rose in general during the two-year period, from 1,630 in January 1943 to 2,067 in January 1945, with a peak of 2,227 in March 1944. Approximately 58 per cent of the employees were foreigners. The average work-week was 55-60 hours, with Saturday afternoons and Sundays normally free.

43. The plant was working below its capacity measured in terms of floor-space and equipment. The striking variations in output per worker indicate the margine of increased output possible in many months, had deliveries of components for assembly come regularly from Schweinfurt.

MONTHLY BEARINGS OUTPUT PER WORKER

	1943	1944	1945
January	77	92	68
April	97	62	
July	71	98	

Attacks and Damage

44. The plant was the target of nine small precision attacks in January and February 1944, eight of these by RAF Mosquitoes. Only one hit resulted from all these raids. On 8 February 1944 a single 500-lb HE bomb hit Bldg 11, housing machines for needle-bearing production, and destroyed one grinding machine and slightly damaged 20 other grinders. There was no fire; damage was from blast and falling drbris. The building was quickly repaired without hindering production; and even the damaged grinding machines were back in operation in two to three weeks. Total cost was reported as RM 75,000.

45. The only other hits came from three bombs in a raid of 21 March 1945. Six automatics were damaged, but the slight curtailment of production was not noticeable in the general collapse as the front approached.

46. The Wuppertal area was the target of two area raids by the RAF on 29/30 May 1943 and 24/25 June 1943, when almost 3,500 tons of HE and IBs were dropped, but the plant was not hit.

Production Loss

47. The effect of the 24 June 1943 area raid, which resulted in widespread devastation of Elberfeld where most of the plant's workers lived, is sharply marked. Though the plant was not hit, it was forced to close completely for several days because of the resulting absenteeism. In all, 70,000 hours were lost because of this raid:

June 1943	12,000 hours lost
July 1943	30,000 " "
August 1943	28,000 " "

The percentage of absenteeism went up to about 10 per cent during this period as a result of the raid. Production declined correspondingly, the August output of 103,786 bearings being the low for the two year period. The curve does not show clearly, however, that recovery was complete by September, since the removal of production equipment to the cellar, ordered after the August raid on Schweinfurt, held output down.

48. The one bomb falling in the needle-bearing department in February 1944 brought a decline from a monthly rate of production of 80,000 bearings to an output of 33,000 for the month of 56,000 for March. The drop in production of all bearings during the first few months of 1944 is partly the result of this decline in output of needle bearings and partly the result of lost time throughout the factory because of air-raid alarms. During the first four months of the year, an average of 7.5 per cent of available working hours was spent in shelters.

49. After the wartime high production of August 1944, the subsequent decline to output reflected the transfer of needle-bearing facilities to the Kugelfischer subsidiary in Berlin, Nord-deutsche Kugellager Fabrik. According to the plan for increased efficiency facilities for small-bearing production were simultaneously shifted from Berlin to Elberfeld, but without quite compensating for the drop in piece production due to the loss of needle-bearing output. These fluctuations were really unimportant over longer periods: the essential fact was the steady output of medium and large bearings, whose constant trend shows only minor variations caused by temporary shortages of components for assembly. These types were Jaeger's main contribution to the German war machine, and they flowed without interruption into munitions manufacture.

D. 2. Robert Kling, Wetzlar

The Plant and Its Importance in the Enemy Economy

50. The plant of Robert Kling, Wetzlar, although not a target of

precision bombing attacks, nevertheless presents an interesting example of the part the small, independent producer played in the overall German bearings picture during the period in which the Allied air offensive was attempting a knock-out blow at the main centers of the industry. From a very small output at the beginning of the war, Kling gradually increased production so that in 1944 output totalled 1,261,474 bearings, an increase of 54 per cent over the previous year. This was 1.5 per cent of total German production. (Table 27)

51. Expansion of Kling's plant compensated for destruction elsewhere. The Steindorf dispersal plant was to protect grinding machines of the type destroyed at VKF/Bad Cannstatt; and the medium-bearing plant at Albshausen was to make up for bombed-out facilities at Villar Perosa, Italy.

52. Kling's main plant, located in Oberbiel, about six miles east of Wetzlar, is equipped to manufacture complete ball and roller bearings, with the exception of balls, and consists of 11 buildings on six acres of land. It is of fairly modern construction having its own electric power facilities with water-power turbines. Ordered to disperse following the raids on Schweinfurt, Kling set up five dispersal plants in the vicinity of the main plant, the first production from them being forthcoming in November 1943.

53. Accompanying the increased production was a steady growth in the labor force, the number of employees rising from 479 in January 1943 to a peak of 1,124 in December 1944, of whom almost 50 per cent were employed in the dispersal plants.

Effects of Bombing

54. Since Kling never was a target of attack, any decreases in output must necessarily be attributed to indirect effects of bombing. It is significant, therefore, that the general upward movement of the production curve was halted temporarily, coincident with the establishment of the dispersal program in October 1943, and output fell from 81,463 in September to 47,532 in December. The upward trend was resumed again as the dispersal plants got under way, and a war time high of 137,534 bearings was reached in August 1944. Further dispersal to two new sites in the fall of 1944 held production down from this August peak and it fell gradually to 108,209 in December. However, 1944 shows an overall increase of more than 400,000 bearings over 1943.

55. Loss of productive work hours due to air-raid alarms, transportation difficulties and sickness was a contributing factor to this decrease in production. The following table indicates the increase in hours, the maximum being reached in the last quarter of 1944 and early 1945.

Percentage of Productive Work Hours Lost	
1943 - 3rd Quarter	10.0%
- 4th Quarter	10.6%
1944 - 1st Quarter	13.9%
- 2nd Quarter	14.3%
- 3rd Quarter	16.8%
- 4th Quarter	20.1%
1945 - 1st Quarter	27.4%

56. Monthly bearings' output per worker, after rising from 120 in January 1943 to 173 in August 1944, declined again to about 100 in December 1944.

57. Balls, for which Kling was dependent on outside sources, became an increasing problem as supplies were never sufficient to permit the assembly of all the components manufactured. At the time this plant was visited, 300,000 - 400,000 bearings were still on hand, lacking only the balls for completion. Oil shortage was another constant difficulty and resulted in many machines being kept idle for long periods.

TABLE 27

ROBERT KLING-WETZLAR
MONTHLY PRODUCTION OF FINISHED BEARINGS
1943 - 1944

	Ball Bearings (mm OD)			Thrust Bearings (mm OD)		Cylindrical Roller Bearings (mm OD)			Long Rollers with Retainers (mm OD)			
1943	-62	-120	-240	-62	-240	-62	-120	-240	-62	-120	-240	Total Bearings
Jan	14,017	3,773	-	11,110	457	9,158	3,890	2	13,540	978	-	56,925
Feb	10,049	3,282	-	11,937	3,041	6,702	2,911	4	18,858	563	27	57,374
Mar	14,882	5,311	-	17,267	5,457	9,440	3,387	-	23,282	1,792	2	80,920
Apr	16,264	6,685	-	15,068	6,511	6,238	4,709	15	25,530	2,545	120	83,685
May	20,356	5,169	-	7,520	4,803	12,346	3,058	5	29,435	7,096	1,324	91,112
Jun	13,255	3,780	-	1,196	8,067	9,334	3,383	1	23,968	1,886	2,220	67,090
Jul	11,402	3,252	-	10,570	5,957	11,542	5,500	-	23,804	1,904	1,844	75,775
Aug	14,150	4,834	-	11,525	4,467	10,300	4,657	59	21,999	1,218	29	73,244
Sep	24,597	1,692	-	9,767	3,611	8,424	7,957	131	22,746	2,026	518	81,463
Oct	11,675	2,548	-	4,124	871	6,242	3,262	112	24,934	1,820	920	56,508
Nov	8,067	3,204	-	5,689	1,701	5,883	3,288	4	18,131	1,992	1,495	49,454
Dec	12,623	3,939	-	917	1,457	5,647	3,718	16	15,466	2,830	919	47,532
TOT:	171,337	47,569		106,690	46,400	101,256	49,720	349	261,693	26,650	9,418	821,082
1944												
Jan	17,236	1,207	1,035	7,293	3,097	4,647	5,048	510	23,727	1,848	182	65,830
Feb	44,193	3,041	147	15,974	2,454	12,524	1,677	697	30,929	1,342	-	112,978
Mar	26,437	872	65	16,061	4,638	16,475	6,474	1,160	29,094	1,180	33	102,489
Apr	23,782	1,757	3,635	3,437	5,476	5,454	4,857	857	30,999	2,124	1	82,359
May	24,024	1,814	4,972	1,393	3,326	16,417	5,448	601	22,361	1,328	54	81,738
Jun	29,505	3,255	1,106	14,141	8,120	7,682	5,929	2,191	25,298	2,111	841	100,179
Jul	23,690	1,412	704	34,986	561	21,214	7,932	1,958	31,651	582	641	125,331
Aug	45,665	658	713	30,875	2,038	12,883	9,038	1,065	30,323	2,128	2,147	137,534
Sep	31,776	1,436	213	28,158	36	7,446	7,410	2,183	28,770	4,892	1,311	113,631
Oct	28,865	1,968	-	12,217	7	22,092	6,396	2,532	36,719	3,171	733	114,700
Nov	52,583	5,053	6	5,195	5	6,586	6,859	3,682	29,591	5,912	324	115,796
Dec	49,668	4,082	-	10,069	-	7,331	5,142	3,118	27,243	1,747	509	108,909
TOT:	397,424	26,535	12,536	179,799	29,758	140,751	72,210	20,554	346,705	28,366	6,776	1,261,474

D. 3. Deutsche Kugellager Fabrik, Leipzig

Introduction

58. The Deutsche Kugellager Fabrik (DKF) of Leipzig, one of the larger independent manufacturers of anti-friction bearings in Germany, was affected only slightly by the bomber offensive directed against the bearings industry. Efficient management maintained annual output at over 1,000,000 bearings during 1943 and 1944. Its share in German output was 7.2 per cent of the industry's piece production and 5.9 of value, the difference resulting from specialization in machine bearings.

The Plant

59. DKF consisted of two main plants in Leipzig, Works I in the Pragwitz area and the larger and more modern Works II in Bohlitz Ehrenberg. A complete line of ball, needle, and roller bearings was manufactured. Approximately 50 per cent of the output fell within the medium size ranges, with emphasis on special bearings largely for aircraft applications. Although production remained almost stationary, at about 100,000 bearings per month, the labor force rose steadily from the July 1943 total of 1177 to 1693 in December 1944. (Table 28 - Production and Labor Force 1943-1944)

60. The increasing tempo of the aerial attacks on Leipzig decided DFK officials to disperse part of their ball and needle bearing equipment to Meerane in May 1944. The subsequent raid of 7 July 1944 on the plant resulted in further dispersal, especially of aircraft bearing manufacture, to a cave in Zwickau in August 1944. The dispersal effort explains the drop in output per worker, from 81 in July 1943, to about 53 at the end of 1944.

The Attacks and the Damage

61. On 7 July 1944, DKF was attacked for the first time by Eighth AF when 48 B-17s unloaded 300 500-lb GP and 164 500-lb IB bombs over the target. In Works I, three HEs and four IBs destroyed the transformer station and damaged machinery in the tumbling department. Four HEs hit the grinding department in Works II and damaged 26 machines, mostly obsolete ones in the retainer department.

62. Numerous RAF area raids were directed against Leipzig but only in the raids of 20 February 1944, 11 September 1944 and 6 December 1944, did bombs fall on or near the plant, and these caused but minor damage.

Effects of Bombing and Recuperation

63. At the time of the 7 July raid, a slight downward trend in overall production was already evident, due largely to the movement of ball and needle equipment to Meerane which began in May. The raid damage, especially a seven-day power shutdown, accelerated this trend. Output fell from 104,000 bearings in April to 56,000 in July. Thereafter recovery, retarded only slightly by the establishment of the Zwickau cave in August, was rapid, and was almost completed by September. At the most, a cumulative loss of one month's production at the April level of output is attributable to the combined factors of dispersal and air-raid damage. The relative importance of DKF was almost exactly the same in December 1944 as in July 1943, though its steady output during the industry's decline in the spring of 1944 had made its share temporarily larger.

TABLE 28

DEUTSCHE KUGELLAGER FABRIK, LEIPZIG

TOTAL PRODUCTION OF BEARINGS IN (THOUSANDS)

	1943	1944	1945
Jan	87	105	108
Feb	99	104	88
Mar	94	100	80
Apr	90	104	
May	92	92	
Jun	94	80	
Jul	95	56	
Aug	92	81	
Sep	103	97	
Oct	101	93	
Nov	113	106	
Dec	109	87	

LABOR FORCE

	1943	1944
Jan		1350
Feb		1415
Mar		1450
Apr		1475
May		1509
Jun		1530
Jul	1177	1551
Aug	1182	1573
Sep	1228	1602
Oct	1250	1628
Nov	1275	1671
Dec	1300	1693

(SOURCE: PLANT RECORDS)

D. 4. Georg Muller Kugellager Fabrik

Introduction

64. The Georg Muller Kugellager Fabrik of Nuremberg specialized in high-precision ball-bearings of the small sizes, for use chiefly in blind-flying instruments, compasses, and optic equipment. While never a target for precision attack, it is interesting nevertheless, because its steady rise in output was dramatically cut off by the area attacks on Nuremberg in the period after October 1944.

The Plant and its Function

65. The George Muller Kugellager Fabrik consisted of two plants: (1) The main plant, located on the outskirts of Nurhberg, with about 350 machine tools for making small bearings; (2) A dispersal plant at Ansbach which had been moved underground in February 1944. The plants together were a complete ball-bearing manufacturing unit, with the balls for both plants being manufactured in Ansbach. Approximately one-third of the bearings produced were high-precision types and the rest were regular precision bearings. They varied in size from three-mm bore to 52-mm outside diameter, although a few bearings up to 110-mm outside diameter were also made.

66. The output of the plant rose steadily in 1943 and 1944, from 335,000 bearings in January 1943, to 628,000 in November 1944. The increase was partly the result of the industry's rationalization program, under which Muller concentrated on the extra small and small bearings. A growth in the labor force accompanied the increased production, employment rising from 1,200 in July 1943 to 1,600 in December 1944. That the rationalization increased efficiency in shown in the rise in monthly output per worker from 335 bearings in July 1943 to 410 in August and 400 in December 1944.

Effects of Bombing

67. Although neither the Nurnberg nor the Ansbach plant was a target of precision attack, the Nurnberg plant was hit in two RAF area raids on 26 February 1943, and again on 21 February 1945. In neither case was there any damage to productive processes.

68. From the beginning of the war until the end of February 1945 there were 19 area raids directed against Nurnberg, nearly all by the RAF. Production statistics seem to bear out plant officials' claims that before October 1944 these raids had little effect in interrupting the normal life of the city of output at the plant. Absenteeism averaged only a negligible three per cent and production increased steadily. However, beginning with the attack of 19/20 October, when 263 Lancasters

of Bomber Command dropped 350 tons of HE and 545 tons of IB bombs on Nurnberg, production at Muller began to fall. The sharpest drop came in January 1945, following the RAF8s heaviest raid of the war on Nurnberg on 2/3 January, in which 514 heavies dropped 1,825 tons of HE and 479 tons of 4-lb IBs.

Production of Finished Bearings

1944	Total
October	615,325
November	627,859
December	602,209
1945	
January	393,569
February	176,246
March (to 20th)	103,964

69. The city's residential districts were almost completely destroyed and the workers were kept busy digging themselves out of the ruins. Later area raids made conditions even worse. Absenteeism increased to 15 - 25 per cent and rose as high as 50 per cent at one time. Utility services were disrupted and lack of current for about two weeks completely shut down the plants. Destruction to the internal transportation system made it impossible for workers to get from their homes to the plants. January production amounted to only two-thirds of the December output and February production was less than half the January output. The continued area raids made any considerable recovery impossible.

CHAPTER FIVE: Dispersal from Schweinfurt - Methods and Costs

General Pattern

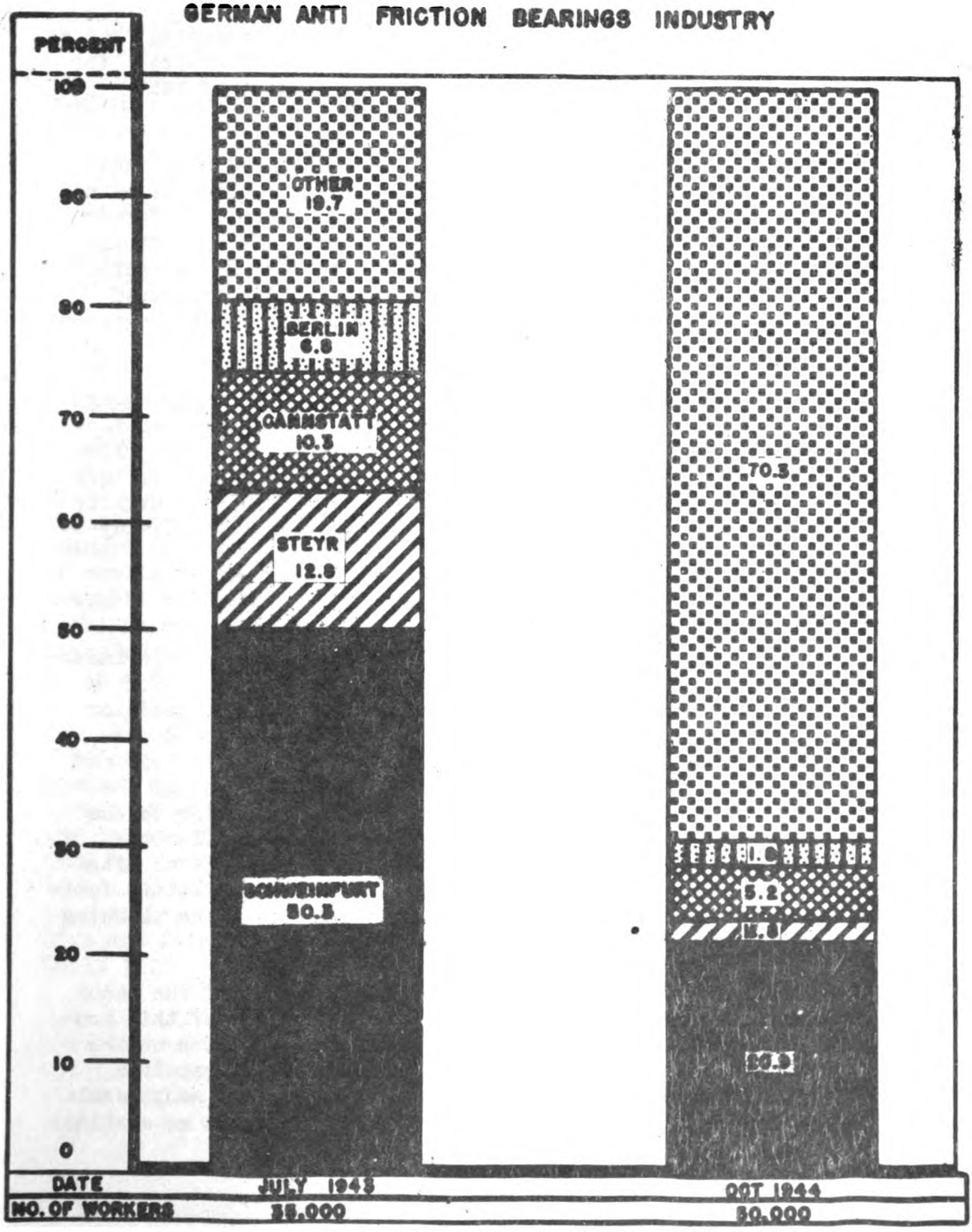
1. When the Flying Fortresses of the Eighth AF first struck at Schweinfurt, they found there a concentration of bearings production which had no equal in Germany. The factories within the city were turning out 52 per cent of the total German production of anti-friction bearings and were employing 50 per cent of the labor force of the entire industry, (Figure 14 - Concentration and Dispersal of Capacity, July 1943 - October 1944)

2. The largest plant was that of Kugelfischer Georg Schaefer AG, (FAG) where 27 per cent of German bearings were manufactured. The two plants of the Vereinigte Kugellager Fabrik A.G. (VKF) accounted for 25 per cent of the national bearings output. In addition to these productive plants, each firm had head offices but these were relatively small. VKF, however, had only about two-fifths of its activities in Schweinfurt, plants in Bad Cannstatt/Stuttgart and Berlin/Erkner were major productive units. The organization for administration was triangular, with the head office located at Schweinfurt coordinating the activities of the Schweinfurt, Stuttgart, and Berlin plants. As dispersal gained importance, each of these sites became the center of a distinct dispersal pattern.

3. Dispersal first became an officially encouraged policy in May 1943, when the German Air Ministry sponsored the plan as a safeguard against air attack. Previous steps along this line had been of minor importance, the only significant exception being Kugelfischer's development of the Ebelsbach ball plant in 1942. Then, when air attacks became an imminent possibility, the major firms selected sites and began preparatory construction or conversion. On the eve of the attacks dispersal was as yet mainly in the preparatory stages. All together 10 per cent of the machines belonging to the Schweinfurt complexes of both FAG and VKF and been located in dispersal plants.

4. The impetus to carrying out the dispersal program was the onset of attacks, and particularly the 14 October 1943 raid, the most effective of all. Later raids of greater tonnage (in February, April and October 1944) caused less damage to productive facilities, partly because there were fewer facilities left to hit in Schweinfurt. This change is illustrated in the case of VKF in Exhibits P and K, which, by showing the change in the distribution of machines between main and dispersal plants, also brings out how radically the dispersal program changed the importance of Schweinfurt as a manufacturing center and as a target. Through dispersal both firms were enabled to achieve a substantial measure of recovery and at the same time make themselves more secure from damage from later raids.

CONCENTRATION AND DISPERSAL OF CAPACITY BASED ON EMPLOYMENT



SOURCE: EMPLOYMENT DATA - SONDERRING WOLZLAGER

FIGURE 14

5. In setting up dispersal plants, both firms tried in general to make use of pre-existing industrial facilities which at the time were performing some function of lower priority in the war effort. Textile mills were a favorite, both firms having taken over a number of spinning and weaving establishments in various scattered locations. Two stonecutting plants to which FAG moved some of its production, including that of large-size bearings, proved to be especially satisfactory choices, for their sturdy foundations were well adapted to the support of heavy machine tools.

6. In other cases machines were moved into underground or semi-underground installations which possessed the added advantage of being less vulnerable to damage. In one instance VKF took over some former munitions storage-bunkers built like cellars and entirely underground except for the roofs, which were made of heavy concrete and protected by grass-camouflaged soil. Later the same firm took over an unused gypsum mine in Neckarzimmern, which was converted into a huge underground plant.

7. In general it was desired to obtain buildings strongly enough constructed to take the semi-heavy machinery used in bearings manufacture; hence the prevalence of textile and other mills. Labor supplies also had to be considered, although often the main plants sent workers to make up shortages. Last of all the site had to be handy to utility and transportation services, which was usually the case with already-existing factories.

Dispersal by VKF

8. The danger implicit in the concentration of the bearings industry in Schweinfurt was recognized by VKF even before the war. Such a consideration played at least some part, for example, in the decision to build the plant at Berlin-Erkner in 1938, rather than expand pre-existing plants. After the war had begun, officials began to talk and write memoranda about the desirability of moving machines out of the main works, but little was actually done along this line prior to the first air attack in August 1943. The company met with indifference when it sought to obtain facilities and materials, and to get permits and assistance from the government. At that time there was little feeling of urgency about the program, which remained mostly in the planning stage.

9. The first move had been taken in 1941, when part of the manufacture of solid cages was selected for dispersal. Choice of this process seems to have been based on the vulnerability of the dies on the machines, which were difficult to replace. A second plant received other cage-making processes in 1942. Work was begun on two additional dispersal points at Bayreuth and Mainteus in early 1943, but no machines

had actually been sent there prior to the raids. On the eve of the attacks, VKF had dispersed only 92 machines, amounting to three of the total in its Schweinfurt complex.

10. The first raid in August 1943 did not cause any great hastening of the dispersal program. A few additional machines were added to the totals already in the previously selected sites. One new development was the sending of 11 ring-fabrication machines to the SKF plant in Puerstein, Czechoslovakia, which eventually received a total of 64 machines from Schweinfurt. As Puerstein was organized to a separate firm owned by SKF (Sweden), but not coming under the direct control of VKF, special arrangements had to be made to get around the problems of ownership and control which arose. Dispersed machines were regarded as having been bought by SKF Puerstein, but VKF sent along technical assistants to augment the labor force. Disposition of items produced came under the direction of VKF Schweinfurt.

11. Altogether 76 machines were dispersed during the two month interval between the August and October 1943 raids.

12. The attack of 14 October changed the pace of the dispersal program. With fear of further attacks serving as an impetus, moves which had previously existed only as plans were made actualities. A total of 549 machines was dispersed from VKF's Schweinfurt plants during the next four months. Priority of movement was given to departments damaged in the raids, as is illustrated by the case of the production of smallest-size bearings. Buildings housing the hard-processes and assembly had been totally wiped out in the October raid; so the remaining machines were quickly moved to a nearby shoe factory. Later they were transferred to Liebauthal, where a dispersal plant had already been set up in a former labor service camp.

13. The greatest single exodus was fromthe heavily hit ball department, where 21 per cent of the machines had been put out of commission by the damage to Works II. One hundred and fifty-four machines were sent as an addition to the existing facilities in Bayreuth. With the arrival from Schweinfurt of 62 ball-making machines Mainleus also took on the function of a ball producer. Both these figures were augmented by the re-routing of new machines previously destined for the main works. By the end of February, just before the attacks on the 25th and 26th, 40 per cent of ball production had been dispersed from Works II.

14. Later raids in July and October brought additional damage to the main ball works; so its dispersal was at all times given high priority. Machines left in Schweinfurt were protected by concrete blast walls; this measure along with dispersal explains the diminishing loss to the department. At the end of March 1945, shortly before

the arrival of American ground troops, Works II held only 26 per cent of the machines used for ball production by the Schweinfurt complex. If one also takes account of the machines dispersed to Neckarzimmern, the percentage reaches the even more impressive low of 20 per cent.

15. Damage to FAG's ball production incurred through the raid on its dispersal plant in Ebelsbach made VKF feel wary about its two balls plants at Mainleus and Bayreuth; so it was decided to send some machines to the underground factory which was being developed at Neckarzimmern. This transfer, begun in the spring of 1944, was accelerated after the July raids, the 109 machines being dispersed during the period between 22 July and 9 October. At the end of March 1945 its ball-manufacturing machines totalled 161, as compared with Bayreuth's 206, Mainleus' 194, and Schweinfurt's 136.

16. Concurrently with this dispersal of ball manufacture, other new plants were being developed as well. In general dispersal took place process-by-process, with, for example, a certain type of ring production and assembly being moved to Burstein. Cages, rollers, and balls would be made elsewhere and then brought there for final assembly. A general picture of the flow of dispersal may be obtained from Exhibit K, which lists the machines which had either been transferred from Schweinfurt, or if newly bought, had been re-routed from the main plant.

17. Another casualty in the October raid had been the main offices, which were located within the area of Works I. As a result the direction of the entire firm was transferred to the nearby resort town of Bad Kissingen. Here were located the executive offices and the bulk of the firm's records.

18. Damage to the assembly department in Works I during the February raids, when 15 of its machines were destroyed out of a total of 132 of this type in both plants, stimulated the growth of a dispersal plant in Grettstadt. This was to house part of the assembly and final inspection of bearings, and in addition was to have a warehouse for completed components which it would subsequently use. Other moves at this time included the transfer of some production of tapered and spherical rollers, the stamping of pressed cages, and the soft processes for ring manufacture. An order from the General Commissioner (Kessler) directed the transfer of some tool-room machines to Zeil, which was also to house the construction and machine offices which had been hit in Schweinfurt.

19. In addition to the moving of productive facilities out of Schweinfurt, there was also a certain amount of dispersal of storage points. It has already been mentioned that Grettstadt had a warehouse for completed components. Stores of finished bearings were lodged in other places, including barracks in Bad Kissingen and sections of

Schweinfurt.

20. Parallel with this disposal program came efforts to protect the machines remaining in Schweinfurt. Blast walls and protective roofs were built round machinery, as in the ball plant. Some machines were moved into basements. The upper three stories of the six - story building in Works I were abondoned or used as stores, and machines were moved to lower floors.

21. The ensuing months brought for the most part only minor changes in the dispersal pattern. The tool-room machines were sent to Rottershausen rather than Zeil, partly because VKF feared that bombers headed for the nearby FAG plant at Ebelsbach might accidentally drop a few bombs on Zeil instead. Rottershausen also received machines for the hard ring processes in addition to those it already operated. The most important development was the decision to build the underground plant at Neckarzimmern, which will be described later.

22. VKF never dispersed all the machines of a given process or step in manufacture. As a result, in March 1945 the main works in Schweinfurt could still perform any function which they had prior to the attacks. Their production was a much-shrunken replica of the former set-up.

23. When the pace of Allied aerial attacks began to increase and the bomb-loads mounted, it was felt that the mere removing of facilities from the city of Schweinfurt was not enough to provide sufficient safeguards against vital damage. This led to the decision to develop an underground plant at Neckarzimmern, a village near Heidelberg. Work started in April 1944 in the caves and tunnels of this unworked gypsum mine which had previously been used only as a munitions store. Ceilings were plastered, extensive power and lighting facilities were put in, and a giant air-conditioning system was installed. The greater part of the machines which VKF had ordered as part of the industry's expansion program were to be sent here, as well as additional important facilities dispersed from the various main works. In this latter category, highest priority was given to roller production, which was started in the fall of 1944, using machines brought from Cannstatt. The Schweinfurt complex had, up to the end of March 1945, contributed a total of 288 machines, of which approximately half were used for the production of balls.

24. At the time of capture, work on Neckarzimmern was well advanced but by no means complete. It was planned to move other facilities there until eventually it would become a self-contained fourth complex similar to Schweinfurt, Cannstatt, and Erkner.

25. The extent to which VKF Schweinfurt carried its dispersal program may be judged by the following table which whows the percentage

share of main and dispersal plants at recent dates in various categories.

TABLE 29

DISTRIBUTION OF CAPACITY IN VKF, SCHWEINFURT COMPLEX

	% in Schweinfurt	% in dispersal plants
Output of Finished Bearings (Feb 1945)	47	53
Ball Production (Jan 1945)	46	54
Labor Force (15 Feb 1945)	41	59
Machines (31 Mar 1945)	42	58

(Source: Plant Records)

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26. This table not only shows how widespread dispersal was; it also illustrates the previously made point that as a target, Schweinfurt had lost a great deal of its importance as compared with pre-attack days in 1943.

27. To be complete, a discussion of VKF's course of reaction to the effects of air attacks must also make mention of subcontracting. The firm seemed in general rather reluctant to make use of this system, claiming that it increased costs to the extent of 2.3 per cent of their gross income. Work sub-contracted was of a variety of types, including truning and pressing done by FAG and Siegerlander Aktion, ring processing by SKF Paris, cage-making by Hunersdorf and Buhrer of Ludwigsburg, and needle manufacture by Groz of Ebingen.

28. Reconstruction, dispersal and sub-contracting enabled VKF to achieve a substantial degree of recovery by October 1944, a recovery which probably would have continued but for the general collapse in German industry towards the end of the war. In October production of finished bearings inthe Schweinfurt complex had risen to 1,631 thousand, as compared with 1,727 thousand in the pre-attack period of July 1943.

Plants were evidently able to operate efficiently in spite of the handicaps resulting from the air attacks, as indicated in the following table. This shows that, relative to the labor force involved, production fell little; relative to machine in use, it actually rose.

RATIO OF PRODUCTION TO PRODUCTIVE FACILITIES AT VKF

TABLE 30 (Schweinfurt Complex)

Monthly Output of Finished Bearings

	Per Machine	Per Worker
August 1943	506	262
October 1943	405	179
February 1944	338	154
July 1944	506	226
October 1944	581	246

(Source: VKF Records)

29. Material available was not sufficient for an accurate appraisal of the cost of VKF and the economy in general involved through the dispersal program. One indication is given in the following table showing additions to capital investment over the raid period. This would also involve expenditures in main plants and in other ways include items other than dispersal, but the greater part was probably accounted for by the dispersal program.

TABLE 31

ADDITIONS TO CAPITAL INVESTMENT
(Millions of Reichmarks)

	Schweinfurt	Cannstatt	Ernker	Neckar-Zimmern	General Reserve	Total
1942	2.5	1.6	3.7	--	2.4	10.2
1943	7.4	3.9	3.0	--	.7	15.0
1944	.8	.7	1.4	11.7	3.0	17.6

(Source: VKF Records)

This brings out quite forcefully the importance of Neckarzimmern as a new development in 1944.

30. The cost of dispersal itself was divided between the Reich

and the firms, the general arrangement being that original costs - cost of getting the plant started, putting up the necessary buildings, and obtaining needed additional machines and installations - were borne by the state, while VKF took care of all subsequent expense. VKF had estimated the original cost of its seven dispersal plants in the Schweinfurt complex as being approximately RM 3,000,000.

31. No estimate of subsequent running expenses is available, but it is possible to comment upon some of the additional costs encountered when production id dispersed as compared with centralization production in one plant or group of plants. Workers had to be sent to new locations, which were usually small country villages with no available skilled labor force. VKF estimates that extra incentive pay offered to console workers for their separation from their home city averaged RM 3.50 per man per day. Also, these workers needed additional transport.

32. Utility consumption increased; in Neckarzimmern, as an extreme example, some 6,000,000 KWH of electricity were used each month to operate the necessary ventilating system.

33. The biggest expense and inconvenience arose from the large amount of inter-plant transport necessitated by the widespread distribution of functions. A ring, after undergoing the "soft-working processes" in Rottershausen had to be sent some 30 miles to Schweinfurt for hardening, after which it went right back to Rottershausen for more processing. Then it was sent to Grettstadt for assembly where it joined cages made in Elfershausen and balls which might have come from Mainleus.

34. VKF estimates that these and other factors increased their costs to the extent of 11.2 per cent of their gross income. The importance of individual items is indicated by the following table, which gives monthly additional-costs arising from production under dispersed conditions.

TABLE 32

MONTHLY ADDITIONAL COSTS DUE TO DISPERSAL AND SUB-CONTRACTING

	Reichmarks
Extra "consolation" payment to workers	210,000
Cost of extra traveling involved	14,000
Additional Freight charges	35,000
Additional intra-plant transportation costs ensuing from damage to plant transport system & conveyors	35,000
Costs arising through division of maintenance and administrative depts.	25,000
Additional power costs	50,000
Additional rent and depreciation charges	155,000
Additional telephone and teletype costs	10,000
Loss of productive efficiency in underground works	50,000
Total additional costs from dispersal	584,000
Total additional costs from sub-contracting	170,000
TOTAL	754,000

(Source: VKF Records)

35. Strategic bombing did not by any means wipe out VKF Schweinfurt production; the truth of this understatement is apparent from previous tables and discussion. Such success as was obtained might be gauged from this following table which, using machine-strength as an index, indicates VKF's productive capacity in comparison with what it might have become had no bomb damage affected it. The " potential " takes account of all machines added through replacement or expansion programs, including machines later diverted to Neckarzimmern.

TABLE 33

POTENTIAL AND ACTUAL NUMBER OF MACHINES, VKF SCHWEINFURT

Date	Potentially: Total machines if no losses occurred		Actually: No of Machines actually in Schw complex	
	No	Index	No	Index
16 August 1943	3185	100	3185	100
15 October 1943	3213	101	2934	92
26 February 1944	3368	106	2985	94
22 July 1944	3475	109	2986	94
9 October 1944	3497	110	2756	87
31 March 1945	3522	111	2808	88

(Source: VKF Records)

Dispersal by Kugelfischer

36. Differences in the firm's administrative and industrial organization change somewhat the details of FAG's counter-measures to the bombing as compared with those of VKF, while leaving unchanged the principles involved. VKF's three complexes were matched here by a firm largely centralized in the Schweinfurt plant, with a single offshoot in existance during the pre-raid period. This was the ball plant at Ebelsbach, which was started in 1942. Although the desire to decentralize played a large part in the selection of this site, its development in general nevertheless represented normal expansion and was not part of the anti-air-raid dispersal program as such. In July 1943 its operations were still tied in with those of the main plant. Only the initial soft-working processes were carried on at Ebelsbach, the balls then being sent to Schweinfurt for further processing.

37. As was true in the case of VKF, the opening of the strategic bombing offensive found FAG with many plans for dispersal but with few in actual operation. Some 18 per cent of the firm's machines were located in Ebelsbach, but work in the other sites was still in its early preparatory stages.

38. The hastening of FAG's dispersal program dates from the first raid of 17 August 1943, which caused severe damage to the main plant. Machines were in general dispersed by processes or departments, with priority going to those sections which had been hardest hit. Disruption of ball production, for example, caused a hastening in the development of Ebelsbach. Installations were enlarged so that balls could receive their entire processing here, removing the necessity for shipment back

to Schweinfurt. By the end of February 1944 the transfer was complete and all ball-making was carried on at Ebelsbach.

39. An American air attack on Ebelsbach in July 1944 caused FAG to introduce a new modification in its program, namely, dispersal of a dispersal plant. Not far from Ebelsbach the firm had already begun work at Ebern on a plant which was to take some minor functions from Ebelsbach. Its operations were now considerably enlarged and many machines were moved here from the bombed ball works, the two plants becoming supplementary contributors towards FAG's ball production.

40. The August and October attacks brought further decentralization in Kugelfischer's operations. Final lapping and inspection of high precision bearings were sent to a former paper mill; the making of small and extra small bearings went to a plant once used to make baby-carriages. Processing of medium-sized bearings went to still another location.

41. Production of large-size bearings, hit heavily by the raids of 17 August and 14 October 1943, was moved in its entirety to a stone-cutting plant. This particular development provides an illustration of the cumbersome complexity sometimes attending decentralization; rings had to be sent back to the main plant for hardening, since difficulty in procuring new hardening ovens had delayed their installation at the dispersal plant.

42. Separate locations were chosen for the making of components. Roller production was moved to a former spinning and weaving plant, where FAG was forced to erect additional new buildings. There was some trouble in obtaining the necessary skilled personnel, the chief bottleneck being their training. In one instance the difficulty was overcome by the National Labor Service which provided girls for work in inspection operations.

43. Some cage production moved to two other sites. Operations in one of these plants were at first handicapped by the fact that the weakness of the floors prevented the installation of heavy presses, and stamping operations thus had to be performed in the Schweinfurt plant. Later special foundations were built so that heavier machines could be moved in.

44. Two plants became assembly points receiving components from other places in the complex. Among the miscellaneous other dispersals were that of grinding-wheel manufacture, and that of the machine repair and tool making to Wurzburg. In this latter city FAG moved into the plant of the machine-tool firm Koenig and Bauer, bringing its own employees along from Schweinfurt.

45. The spring of 1944 saw both major bearings companies turning

their attention to dispersal underground at the behest of the German government. At about the same time that VKF was moving into the tunnels at Neckarzimmern, FAG began to develop its own counterpart in a former calcium mine at Wellen, near the Western frontier of German. 3,000 workers of the Todt Organization began the work of converting and enlarging the tunnels into a plant which was eventually to house all the processes necessary to turn out finished bearings. Its 1,284,000 sq ft of floor space was to be divided into three levels, the uppermost containing day rooms and messrooms for the workers, storage points for raw materials, a heating plant, and a ventilating plant to provide the necessary air conditioning. The second level was to house the machines producing rings. On the third and lowest level were to be located the production of other components such as balls, rollers and cages.

46. The total cost of building this underground factory was estimated at 15 million RM, with the state itself paying for the initial construction. The average cost per square meter of RM 190 compares with a figure of RM 100 for plants built above ground. FAG was to pay the government rent for the use of the facilities, and in addition paid for all the necessary machines. Work was begun in March 1944 and was to have been completed by July 1945.

47. Preparations also included the installation of a transformer underground, the provision of a water supply by the building of a pumping station on the nearby Moselle River, and the laying of a spur line to connect with the railway system. Barracks to house the workers were built on the site.

48. The work of conversion was proceeding apace and some machines had actually been put in operation when the approach of the Allied armies caused the abondonment of the project. Casting about for a substitute, FAG at first decided to move the machines toa salt mine at Stassfurt, in the vicinity of Magdeburg. This site proved to be unsatisfactory and never went into operation, one reason being that the narrowness of the shaft hindered the lowering of machines into the mine.

49. Next FAG decided to bring some of its wandering and hence unproductive machines back to the Schweinfurt area. The Todt organization was to prepare a new underground plant at Kies, which was to house the hard processes for the production of medium-size rings. Its estimated average cost of RM 350 per square meter compares with RM 190 at Wellen and RM 100 in the case of above-ground plants. A large part of the excess was accounted for by the fact that this construction was entirely new as distinct from the operations at Wellen, where tunnels had already been dug. Various necessary input items were estimated as follows:

Labor	-	90,000 man days
Iron	-	115 tons
Cement	-	4,200 tons
Bricks	-	3.2 million units

50. Operations at Kies were to become part of a production cycle which would begin at Schweinfurt and make the circuit of several dispersal plants. All machines left in the main works would be protected with heavy concrete walls and roofs. After forging of rough rings, the soft-working processes would take place in another section of the same plant, and then the rings would be put aboard a train and shipped to Kies. They would become completed rings in the hard-process departments which were to be located there. Another railway trip was to take the rings to Bamberg for assembly, after which the completed bearings would be sent to Ebern for dispatch.

This plan was never put into actual operation, since the arrival of Allied troops put an end to development at Kies.

51. Determination of the additional costs arising from the countermeasures made necessary by the air attacks was not made in the same way here as in the case of VKF, so that a comparison between the two firms is not valid. So far as actual expenditures were concerned, the general rule seems to have been that any purchases or construction which would result in an increase in peace-time capital values to the firm would be financed by them, while other expenses would be paid for by the Reich.

52. Estimates of the monetary value of losses arising from the attacks on FAG follow:

TABLE 34

ADDITIONAL COSTS ARISING FROM AIR ATTACKS ON FAG
(Millions of Reichmarks)

Air-raid damage	71.2
Loss through unused capacity	10.0
Dispersal costs	
Initial costs	
Above ground dispersal:	
Govt - compensated costs	4.9
Costs born by FAG (net additions to capital)	6.2
	14.0
Underground	
Total initial costs:	25.1
Current Costs	9.0
Total dispersal costs	34.1
Cost of construction "bomb-proof" buildings at Schweinfurt (Borne by Govt)	1.0
Increased cost through sub-contracting	1.0
Total	117.3

(Source: Kugelfischer Records)

CHAPTER SIX A Target System Within the Bearings Industry

Ball Production

Introduction

1. The reasoning that directed the selection of the bearings industry as a target system can be stretched one step further. Just as critical equipment cannot be made without its components, among which ball-bearings offered the best prospects for successful attack, so in turn bearings cannot be made without their components, of which the balls offer the best prospects for successful and economical attack.

2. Plausibly it is asserted that the ball department was the most vulnerable department of the German bearings industry; that without balls the effort expended on the production of other bearings components would be wasted, for there could be no assembly; that a much smaller aerial effort would have been necessary to destroy ball production rather than the entire industry. In short, knock out the ball plants and you have rendered the rest of the bearings industry useless. Ball production, therefore, makes an ideal test case all the more since it was heavily hit in the attacks.

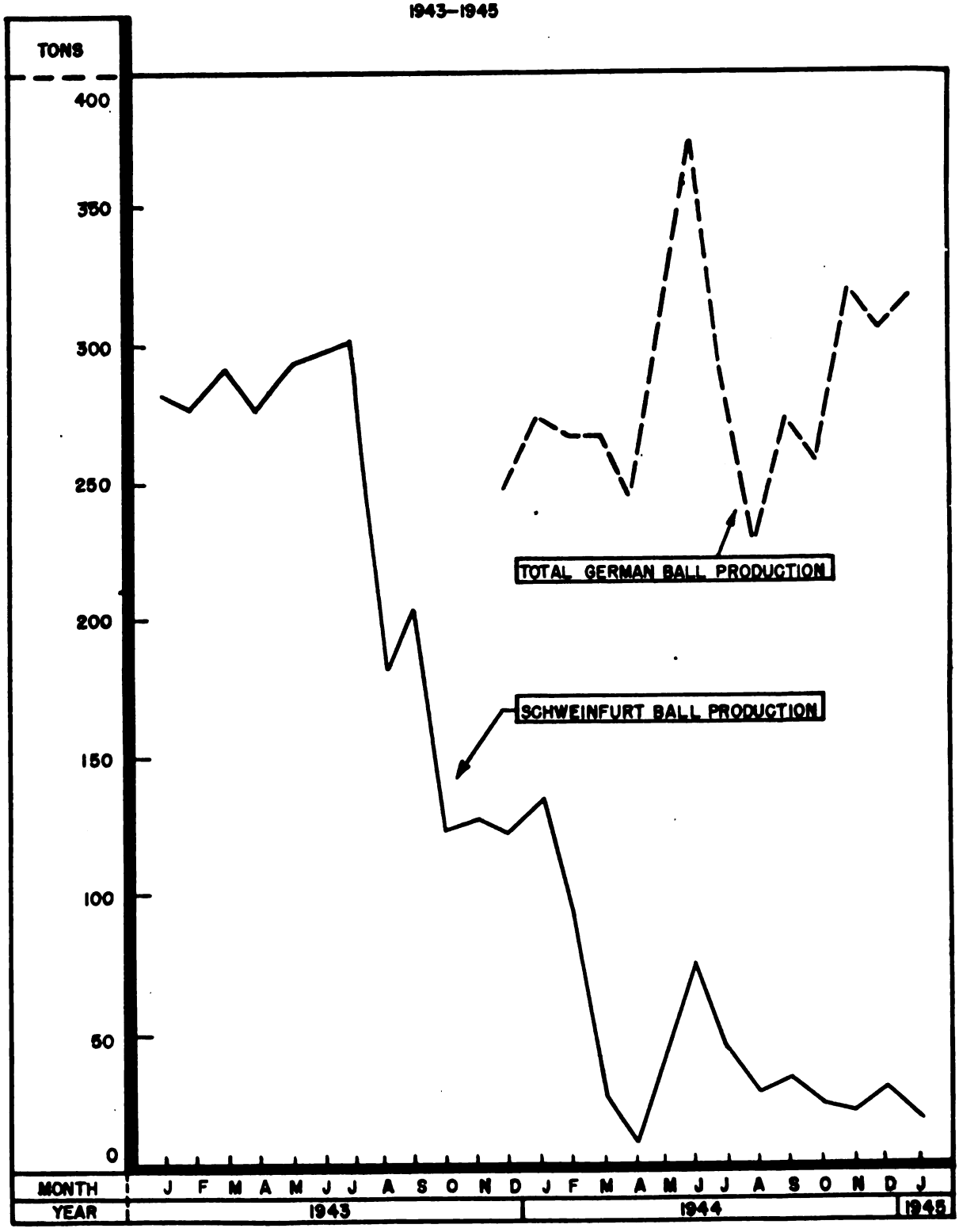
Vulnerability

3. Bearings experts are agreed that balls are the most important component of a ball bearing, for they not only supply the anti-friction quality in a bearing but also carry the load. To function properly they must be made to the highest precision. Tolerances of .000025 inches in diameter and sphericity are not unusual and for precision bearings even a higher quality is demanded. Thus, all grinding and polishing machines are of special design and require special tooling for each size of ball. In addition, normal ovens do not supply the regular temperature necessary for hardening; specially constructed furnaces are required so that the balls will emerge without a blemish. And, finally, specially designed sorting and measuring devices make ball production the most specialized department in the productive process, containing equipment extremely difficult to replace.

4. In an industry already highly concentrated geographically and industrially in 1943, the concentration of ball production was particularly striking with 70 per cent of the industry's requirements being manufactured in the Schweinfurt plants of FAG and VKF (See Figure 15 - Schweinfurt and Total German Ball Production 1943-1945.) Not only did these plants supply all their own needs but they also filled all the ball requirements of their branch factories. VKF/Bad Cannstatt, VKF/Erkner, G. & J. Jaeger, and Norddeutsche Kugellager Fabrik, as well as the full needs of such independents as Robert Kling and, before May 1944,

SCHWEINFURT AND TOTAL GERMAN BALL PRODUCTION

1943–1945



SOURCE : PLANT & MINISTRY RECORDS

FIGURE 15

75 per cent of the requirements of Steyr-Daimler-Puch. Only a minor segment of the anti-friction bearings industry was not dependent upon Schweinfurt for balls; i.e., Muller of Nuremberg satisfied its own needs for precision balls.

5. The German bearings industry realized quite early the peculiar vulnerability of ball production and in September 1941 FAG began construction of a dispersal plant in Ebelsbach whichwas to manufacture only balls, and limited production starting with ball pressing was under way by the end of 1942. Activities at Ebelsbach were, however, intimately tied up with those at the main FAG plant in Schweinfurt, which did the forging and some of the final operations for Ebelsbach. An examination of production statistics reveals that during the first half of 1943 FAG Schweinfurt was turning out 140 tons of balls per month, with approximately 25 tons of this total coming from Ebelsbach but not in all types and sizes.

6. The first raid on the Schweinfurt bearings industry in August 1943 was especially damaging to FAG's ball production with 50 per cent of the machines in this department alone being destroyed. Kugelfischer executives considered this one of the most damaging blows of the entire aerial campaign. In September and October production tumbled to one-third the July output and, considerably retarded by the destruction of 43 tons offinished balls and 379 tons of balls-in-process by the attacks on 24/25 February 1944, did not fully reattain pre-raid levels until June 1944, a cumulative loss of 3.5 months' production.

7. Recovery was possible because of the rapid expansion of the Ebelsbach facilities. Lightly damaged and easily installed machines were moved from Schweinfurt to Ebelsbach and under the supervision of Schweinfurt foremen and engineers the plant was made capable of meeting all demands for various sizes and qualities. Simultaneously the Schweinfurt department was temporarily rebuilt with machines either ordered previously for the expansion program or specially built for this emergency. But by the end of February ball manufacture had been moved completely from Schweinfurt to Ebelsbach and the June recovery to pre-raid levels, previously mentioned, was accomplished entirely by Ebelsbach production.

8. In July the Eighth AF paid Ebelsbach two visits and at the second attempt succeeded in destroying the plant. Production was halted completely but the initial impact of the raid was partly neutralized because about 20 grinding machines intended for an expansion program were rushed in, and by September limited production had been resumed. Further neutralization was obtained by rapid dispersal (1) of undamaged machinery to Ebern, a plant planned in 1943 to make use of the labor in that vicinity and (2) of production of high-precision balls to a small plant at nearby Gleisenau. By December 1944 Ebelsbach, Ebern, and Gleisenau together had reattained the 120 tons monthly that FAG

considered necessary for its own needs. In the meanwhile the firm assembled ball bearings partly stock and partly from balls available because of the previously multiplied capacity of the small firms.

9. VKF ball production felt the effects of the aerial bombardment perhaps even more than FAG; Allied bombs beat a steady tattoo on the ball department from August 1943 to March 1945. Out of a total of 650 ball machines 131 were destroyed and 120 damaged during the course of the raids. This department suffered more damage by far than any other, for over 35 per cent of all the machines destroyed and damaged in the entire plant were in the ball department alone.

10. The aerial onslaught began on the 14 October 1943 when 73 machines were destroyed and 65 damaged in the ball department. Production sank from 158 tons in September to 14 tons in November. Damaged machines were rushed to a large number of firms for repairs. A ball plant at Bayreuth, already in limited production, was rapidly expanding by the addition of 178 machines from Schweinfurt, and another ball plant at Mainleus, already planned, was brought into operation soon after.

11. Recovery of VKF ball production was halted by the RAF attack of 24/25 February 1944 in which 39 more machines were destroyed, and output fell from 61 tons in January to 47 in February. With the Bayreuth and Mainleus plants going full balst, however, and Schweinfurt production restored somewhat, output was approaching pre-raid levels when the raids of 19 and 21 July 1944 again halted the upward trend. Ten machines were destroyed and 34 damaged. More complete dispersal was decided upon and 110 of the 263 machines remaining in Schweinfurt were dispersed, all but one going to the new underground factory at Neckarzimmern. Thus, by the time of the 9 October 1944 raid, 80 per cent of VKF balls were being made outside Schweinfurt and the destruction of nine machines and the damage to 21 resulted in only a slight loss of output.

12. However, these repeated attacks and the attendant effort expended in dispersal kept ball production from even approaching pre-raid levels. The post-raid high point 121 tons was reached in June 1944 and this was never approached after the July attack. However, this is partly attributable to the transfer of 109 ball machines to Neckarzimmern whose production is not included in the VKF figure.

COUNTERMEASURES

13. The German anti-friction bearings industry moved briskly to meet the crisis caused by the damage to their ball departments. Immediate steps were taken to have the four small manufacturers take up the slack by increasing their output of lower precision balls, and Schweinfurt technicains were rushed to Bebruder Heller, Gebauer and Moller, Kugelfabrik Schulte, and Bruninghaus to aid them in improving quality

and quantity. At the same time imports of balls from Sweden were greatly increased. Highest priority was given to the repair of damaged ball machines and it was possible to restore Schweinfurt production in four to six weeks. Planned dispersal of other departments was abandoned in favor of the rapid movement of remaining ball machinery out of Schweinfurt. Ball production in Schweinfurt never totaled more than 18 per cent of the entire industry's output after March 1944 and had dropped to eight per cent by the end of the year.

14. Simultaneously a large cushion provided by the sale of utility balls to users outside the bearings industry was immediately reduced. Delivery of balls for bicycles, furniture, and tumbling was sharply curtailed, VKF alone cutting these shipments (which had averaged 200 tons per month from 1942 onward) to 103 tons monthly in 1944 mostly delivered in the second half of the year.

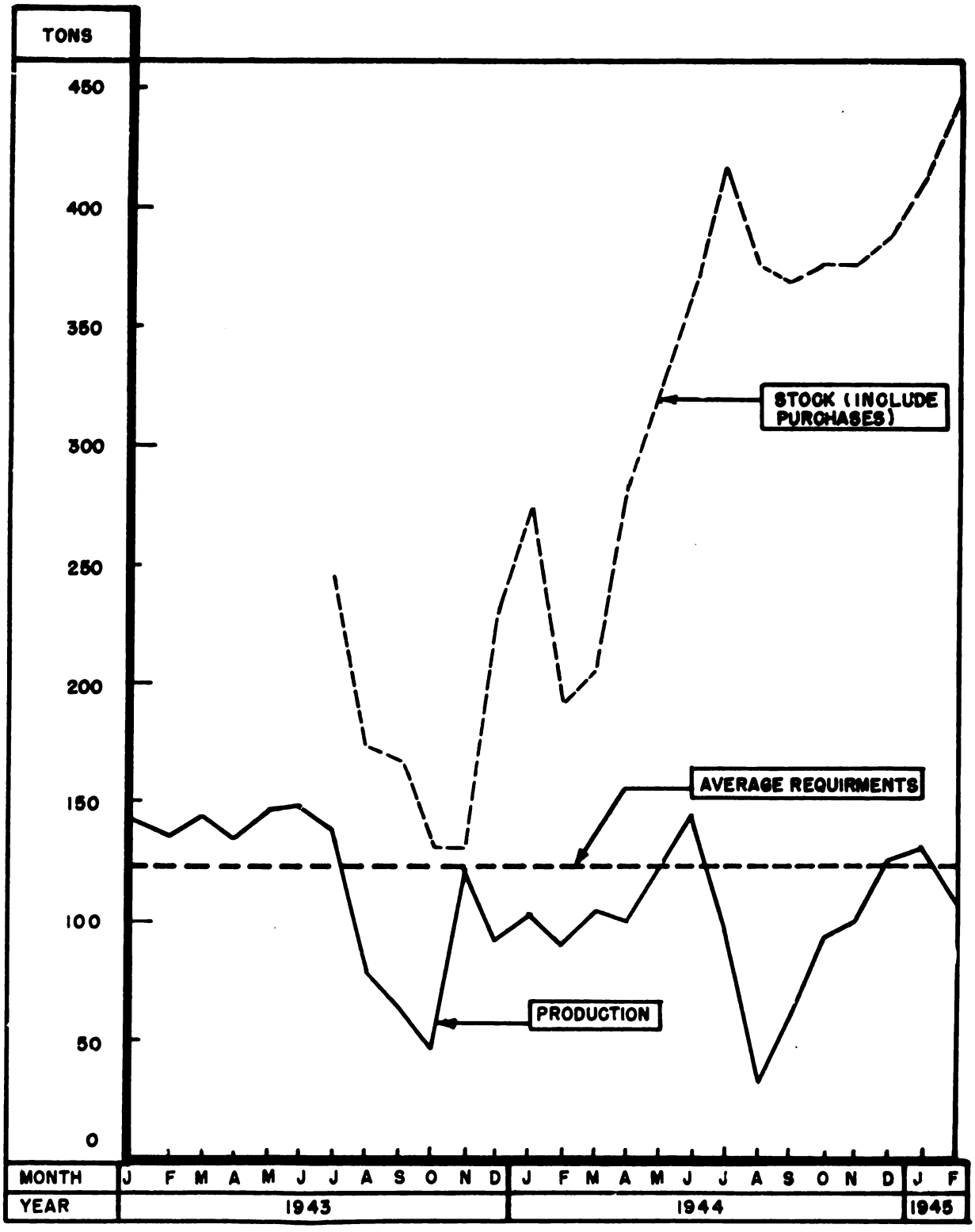
15. FAG, which was hit first, carried only about a month's stock of balls. When this was exhausted they had to be fed by VKF (40 tons of balls in September), the smaller firms, and especially Sweden. FAG executives are agreed that without this outside assistance there would have been an even greater decrease in their output of finished bearings. Thus were they able successfully to weather the October crisis and thereafter balls presented no serious problem and by July 1944 FAG had succeeded in building up a three months' stock. (See Figure 16 - Kugelfischer Ball Production & Stocks 1943-1945)

16. VKF, on the other hand, usually had 500 tons of balls in stock, the equivalent of four month's normal production. Thus, they were able not only to make good FAG's deficiencies but also to supply their own needs from stock when their ball department was smashed in October. Damage to other departments compensated somewhat for the temporary loss of the ball department, and balls never caused a direct decrease in finished bearings production. At the time of the occupation VKF still had 300 tons in stock.

TARGET POTENTIALITIES

17. Recovery of German ball production after the 1943 attacks was materially aided by several additional factors. Quite apart from the fact that Eighth AF had been so depleted by its October raid on Schweinfurt that it could not deal another decisive blow at any part of the bearings industry for a period of weeks, there was the difficulty that to hit a ball department required precision bombing of an accuracy impossible to achieve by high level bombing. Not only was it almost impossible to pin-point so small a target but there was no way in which a ball department could be exactly identified. It has no distinguishing characteristics, and a study of Intelligence evaluations of plant layouts revealed that more often than not, the ball department was improperly

KUGELFISCHER BALL PRODUCTION AND STOCKS



SOURCE: PLANT RECORDS

FIGURE- 16

identified. Indeed, Intelligence was unaware that a plant making only balls existed at Ebelsbach. The plant was discovered quite by accident when smoke screens were set of because of planes flying overhead to other targets; thereafter all Intelligence data referred to it as a complete ball bearing plant. Thus, the raids directed against it were not actually directed against a ball plant. It is interesting to note in this connection that German camouflage was so thorough after these raids that Allied Intelligence believed that production had been halted completely where as it actually recovered to 50 per cent of pre-raid tonnage. The existance of the other dispersal plants housing ball production in Bayreuth, Ebern, Gleisenau, and Mainleus was not even known to Allied Intelligence.

CONCLUSIONS

18. Thus the history of the raids shows how heavily all known ball plants were actually hit. Although it was largely chance that the ball departments rather than some other processes were particularly hard hit the damage could hardly have been heavier had balls been made a specific target within the bearings industry. The difficulty of identifying ball-making departments, and of hitting them, supports this statement. Despite the precision and specialization of the instruments and equipment, the machine building facilities of the bearings and machine-tool industries were able to repair and replace damaged equipment very rapidly. The margin of time allowed by the normal stocks on hand was sufficient for recovery and dispersal, with the assistance of highest priorities for this recovery effort. Dispersal of ball production was readily carried out, since the department was a convenient unit for separate operation and the finished product was compact and easily transportable.

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CHAPTER SEVEN THE ORGANIZATION AND FUNCTIONING OF THE SONDERRING WALZLAGER

1. Under the impact of the Combined Bomber Offensive against the German anti-friction bearings industry in 1943-44, the ministerial agencies for the industry were assigned the task of preventing damage to bearings plants from effecting reduction or delay of armament production. These agencies were the Sonderring Walzlager (SRW), headed in name by Georg Schafer, owner of the Kugelfischer concern, but in fact by Dr Enno Becker and the Schnellaktion organization of Philip Kessler, General Commissioner for the bearings industry after October 1943.

2. Armed with directives from the Speer Ministry giving the highest priority to the industry, Kessler speeded repair of buildings and machines when crisis developed, while the Sonderring took over allocation of stocks, orders, and deliveries between bearings and end-item producers. Together, the organizations made strenuous efforts to assure a continuous flow of supplies of bearings into armament equipment. Their slogan was "Es ist kein Geraet zurueckgeblieben, weil Waelzlager fehlten" (No equipment lacking because of bearings shortages.) The success of these efforts was one of the principal reasons why equipment was not held back because of bearings shortages, in spite of the serious effects of the bombing attacks on Schweinfurt and other centers of bearings production.

Ministerial Controls Before October 1943

3. Before the appointment of Albert Speer as Reichsminister fuer Bewaffnung in February 1942, the bearings industry was not directly controlled by the Reich. Efforts to shape the industry's planning were undertaken by some agencies, such as the Beauftragte fuer Sonderaufgabe in the Luftwaffe (the air forces deputy for special problems) but in general the industry was without central supervision.

4. Since the early years of the Hitler regime, bearings manufacturers were organized in a self-governing agency, the Fachgruppe Treibwerke und Walzlager (the sub-group for Gears and Bearings), affiliated with the Wirtschaftsgruppe Maschinenbau (Trade group for machine construction.) The Fachgruppe chief was Director Hans Cappus. The chief concerns of the organizations appear to have been standardization and business relations before the war; and in addition encouragement of efficiency after the outbreak of war. A letter from Cappus to the members of the Fachgruppe, dated 19 January 1942, urges increased production through raised efficiency, and lists as measures the following:

1 Elimination of non-essential orders
2 Limitation of types

3 Specialization
4 Longer shifts
5 Employment if idle capacity
6 Economy with material
7 Lowering of standards
8 Exchange of methods
9 Continuation of standardization

In order to do these things and thus increase production, the letter closes, "private industry's interests must be put aside." The Fachgruppe had little authority, however.

5. One of the early acts in Speer's administration was the establishment of Hauptringe and Sonderringe (Main and Special Rings) for armament and component producing industries. The Hauptring and Sonderringe furnished an organizational link between the Selbst-verantwortungs organen (self-governing agencies) of German industry, and the formal authority of the state. The leaders of the Rings were representatives of the industries forming the Rings; they were responsible to Speer, however, and derived their authority from his orders. When the Rings were formed, they took over authority and duties from numerous executive or service agencies, and from industrial organizations, many of which remained in existence but with only nominal or extremely limited duties.

6. In the middle of March 1942, the Hauptring Produktionsmittel und Maschinelemente was established by Speer, and within it the Sonderring Walzlager was formed for the bearings industry, with George Schafer, owner of Kugelfischer AG as chief, and Dr Enno Becker as manager. A short time afterwards, when the Speer Office became the Ministerium fur Rustung und Kriegsproduktion (Ministry for Armament and War Production), the Hauptring Produktionsmittel and the Sonderring Walzlager came under the Rustungslieferungsamt (armament deliveries office) of Walther Schieber, in the new ministry. (In the reorganization of the Speer Ministry on 11 October 1944, the SRW was shifted to the Hauptausschuss Maschinen, under Dir Karl Lange. There it was styled formally Sonderausschuss IV of the Gruppe "Fertingungseinrichtungen" (production equipment), though it continued to be called a "Sonderring" in correspondence. Under the new set-up, it belonged to the Technisches Amt, headed by Sauer, of the Speer Ministry.)

7. The Sonderring Walzlager took over from the Fachgruppe measures for increasing efficiency, but placed them on a more formal footing under responsible experts, as the organization plan (Exhibit R) shows. However, as a part of the Reich's administrative apparatus to insure armament deliveries, the SRW was assigned more specific tasks. Its responsibilities were defined as:

Table 36

GERMAN BALL PRODUCTION (Tons)

	Monthly average	VKF Schwein-furt	VKF Disper-sal	VKF Total VKF	KUGELFISCHER Schwein-furt	KUGELFISCHER Ebels-bach	KUGELFISCHER Ebern	KUGELFISCHER Total FAG	OTHERS Steyr Muller etc	OTHERS Gebruder Heller	OTHERS Gebauer & Muller	OTHERS Other small plants	Total Germany
1942				142.6									
1943	Jan				136.2			136.2					
	Feb				133.9			133.9					
	Mar				146.5			146.5					
	Apr			144.9	133.7			133.7					
	May				146.1			146.1		28.0	9.0		350.
	June				150.1			150.1					
	July			166.4	140.2			140.2					
	Aug			112.8	68.6			68.6					
	Sept			157.8	50.1			50.1					
	Oct			75.2	48.1			48.1					
	Nov			14.1	114.7			114.7	12.0	36.0	21.	11.	
	Dec			40.3	82.0	9.9		91.9					248.8
1944	Jan	37.8	23.4	61.2	98.5	8.7		107.2					273.9
	Feb	30.2	17.0	47.2	67.3	17.1		84.4					267.0
	Mar	26.8	42.3	69.1		104.8		104.8	18.0				262.0
	Apr	18.8	39.2	58.0		101.4		101.4					248.0
	May	42.2	37.8	80.0		124.2		124.2					308.5
	June	71.4	49.8	121.2		144.4		144.4		36.0	21.	11.	370.0
	July	42.1	41.7	83.8		91.7		91.7					288.1
	Aug	29.3	52.7	82.0			28.5	28.5	30.0				219.0
	Sept	37.8	55.4	93.2		20.2	37.1	57.3					271.8
	Oct	20.1	73.2	93.3		40.6	47.8	88.4					259.0
	Nov	18.9	79.9	98.8		53.4	46.4	99.8	35.0				320.0
	Dec	26.5	61.8	68.3		69.2	51.1	120.3					305.0
1945	Jan	16.3	67.4	83.7		65.1	61.8	126.9	30.0				314.0
	Feb					61.3	48.3	109.4					

N B Based on Interrogation and best available evidence.

SOURCE: Plant records.

1. Assuring the delivery of the monthly output
2. Increasing production
3. Balancing direct and indirect military against civilian needs
4. Determining and processing duplicate orders

However, the SRW was not armed with powers of compulsion in its efforts to accomplish the tasks set the anti-friction bearings industry.

8. While the Fachgruppe continued an independent existence, what importance it may have had vanished with the formation of the Sonderring.

9. In general, the function of the SRW in 1942 and the first half of 1943 was to act as a liaison office between the bearings industry and its customers; it determined the general needs of the German economy and particularly of the munitions firms, assisted in the placing of orders where capacity was freest, and encouraged timely delivery of important orders. Specific assignment of orders to particular firms was avoided, as was any interference in the business relationship between buyer and seller; the SRW acted at that time merely as processor and arbiter, and waited usually for invitation before it acted. Its activity increased constantly, nevertheless, in the period before the August 1943 raids; the critical ("Engpass") types which it handled had grown by the last half of 1943 to include almost half of the bearings types.

10. This constant growth of bottlenecks is the concrete evidence of the tightness in the bearings situation before the raids. The tightness, which was troublesome rather than restrictive, resulted from the rapid growth of both the bearings and the armament industries and the difficulty of matching their developments in each particular kind of equipment.

11. In order to bring order into the confusion that resulted from rapid but unplanned growth, two long-term programs were worked out. The first was the "Walzlager Aufteilung", or distribution of types among the producing firms. The number of different types made was analyzed, the types not needed were eliminated, and the remaining ones were assigned to the firms best equipped for producing them; some types and sizes were made by only one firm and some by several, but, wherever possible, duplication was avoided and concentration of production encouraged.

12. Simultaneously, a study of the demands of the armed forces was undertaken, and on the basis of the results a systematic expansion of the bearings industry to double its early 1943 capacity was planned and initiated. Existing works were to be expanded and new ones erected by the existing firms. These new plants were located in accord with a systematic dispersal that had as its purpose primarily the decentral-

ization of the industry and a consequent lessening of vulnerability to air attack, and secondarily a tapping of new resources by making use of textile and other plants and their labor in outlying districts. On the basis of a thorough study of the capacity of the industry, the necessary machines were agreed on and actually ordered for the most part before the end of 1943. This was the "Verdoppelung" (Doubling) or "Aufstockungs" (Building-up) program of the bearings industry. It was in large part the work of theindividual firms and such experts as Jurgensmeyer and Schweickartd of VKF, but it was based on the SRW's estimate of the eventual needs of the armament industries and was supported by Speer, who wished to eliminate any possibility of a bottleneck in so insignificant a sector of the economy.

Expansion of the Sonderring's Powers: October 1943

13. The SRW had, thus, a functioning organization and a plan for the development of the industry when the Combined Bomber Offensive struck at the anti-friction bearings industry and its Schweinfurt center in August and October 1943. The 14 October 1943 attack on Schweinfurt was crucial, not alone because of its destructiveness, but also because it made clear to the German high command and armament leaders the design of Allied attack. According to Dr. Becker, the business manager of the SRW, the effect of the attack on the Berlin officials and on the public was disproportionate because the dramatic position of Schweinfurt as a focus of attack had been played up and because the bearings industry had already been considered a production bottleneck in the economy. Speer and other high officials visited Schweinfurt, and in Schweinfurt, Schieber, head of the Rustungslieferungsamt in the Speer ministry, issued an order on 15 October placing all bearings production and delivery under the SRW. Five days later, Speer announced the appointment of General Commissioner for the bearings industry, at the head of a "Schnellaktion Kugellager" (quick action for bearings)also known as "Schnellaktion Kessler" from its head, Philip Kessler of the Bermann Electricity Company of Berlin. Kessler was a member of Speer's Rustungsrat, a special duputy of Speer's for various tasks (such as the designing and manufacturing of special containers for parachuting supplies to the defenders of Stalingrad) and a man of energy and good political connections.

14. Kessler did not set up an elaborate organization, but worked in the main through the SRW. His chief interest was reconstruction and expansion of the industry, and his chief use was in dealing with the suppliers and customers of the bearings firms. The rapid recovery of the industry at the end of 1943 was mainly his work; he obtained machines, labor, and materials for the damaged firms under the unlimited powers given him by Speer. Simultaneoulsy he pushed the dispersal program of the Schweinfurt and other firms, and on the basis of the plans laid before the attacks speeded up its carrying-out. Under his supervision,

a new "Ausweitungsplan" (Expansion plan) was issued in May 1944, to fit the revised demands of the armaments industry, and measures were under taken to procure the required resources in men, machines, and materials for this expansion. After this time, Kessler concerned himself less frequently with the routine affairs of the bearings industry, confining himself to exceptional needs and to the meetings which at various times brought together representatives of the bearings firms and their consumers for discussion of the problems involved in meeting the demand.

15. Immediately on the publication of Schieber's order giving full control of the industry to the SRW, a reorganization of the Ring took place on a plan worked out by Dr. Becker, the effective head. The new functions and organization may be studied in detail in Exhibit P. The key section of the SRW became the Arbeitsring Bedarfslenkung (Labor Force Control Ring), headed by Becker and consisting eventually of about 80 employees at Hassfurt, 23 km from Schweinfurt. This group controlledthe production and distribution of anti-friction bearings; all orders passed through its hands, all deliveries had to be approved by it, and production schedules had to fit its quotas.

16. To meet the immediate problem produced by the October 1943 raid, a freeze on deliveries and cancellation of all orders in hands of the bearings firms were applied. A survey of stocks in the hands of producers and consumers, of bearings currently in production and of imperative needs for the final two months of 1943 for the armament manufacturers, was completed on 6 November. On the basis of this data, the SRW was able to recuire the consumers to work for the most part out of stock and to ship bearings only in case of urgent and immediate need for current production. (Exhibit R)

17. Simultaneously, preparations for 1944 were made. The Main Committees and Rings were required to assembly the needs of their member firms for the first six months of 1944, according to the munitions program, and to include a sworn statement as to bearings on hand. At the SRW these orders were compiled and assembled by sizes, types and months for each committee. To the totalled compilation was added a factor of 10-20 per cent for small or special orders and for repair demands (Klein and Sonderreparature Bedarf), as a safety factor. To this total demand was compared the total capacity of the bearings producers, by sizes and types. The amount short in any size range (the Fehlbedarf) was considered to be on an Engpass basis.

18. In planning the allocations of orders to bearings manufactureres, the SRW first considered the amount of uncommitted finished bearings in the hands of producers, and the amount of uncommitted work in progress, by types and sizes. Allocation for requirements now covered by these sources was given each firm as a production quota ("Soll-leistung") on

a regular delivery basis or on an Engpass basis. (The latter meant at times setting aside the normal work schedule and routing, in order to meet immediately the most pressing needs of munitions firms.) The allocation thus represented the amount of bearings that had to be produced (Soll). It consisted of the total need, as shown by orders, less the uncommitted stocks the bearings firms would have on hand.

19. Stocks on hand with the producers were in general not important, however, representing usually about a month's production. Of these, only about a quarter, or a little over one million bearings, would be uncommitted to current orders. Little account was taken of another stock pile, the bearings in the hands of sales agents of VKF, and FAG, particularly the former. These ran to two or three million, chiefly of types suitable for repair needs for machinery. They were pressed into use only after the October 1943 raid; they were also checked in April 1944.

20. For the first half-year in 1944, the bearings expected to be imported from Sweden were taken into account in coordinating supply and demand. For the second half of 1944 and the first half of 1945, however, this source could not be relied on, and the whole burden was theoretically placed on German producers even though declining deliveries from Sweden continued until October 1944.

21. Although the allocations of orders were basically made only every six months, in practice reallocations had to be made as firms fell behind because of air raids or as cancellations of orders freed capacity. In addition, the estimates of the Committees could not be exact, and toward the end of each six months period, new orders would come in to be either filled out of stocks or assigned for immediate manufacture to avoid a bottleneck. At the end of each six months period, all unfilled orders were considered automatically cancelled and had to be reordered if delivery was still desired.

22. The outlined procedure for adjusting production to anticipated demand was followed with only minor administrative changes for the three half-year periods in 1944 and early 1945. On the basis of the planned production, the SRW's sections on labor and materials supply would in turn compare the available resources with the needs of the various firms, allocate them proportionately and initiate (with Kessler's backing when necessary) requests for additional workers, steel, or machine tools.

23. Coordination of supply and demand was not solely or even chiefly a matter of advance planning, however. Under the conditions of attack and shifting demands for new designs and programs, it became a matter of constant adjustment of shrinking supply to increasing demand; and this balancing was the chief contribution of the SRW to countering the

effects of Allied raids. Dr. Becker described the measures taken, in a letter to General Commissioner Kessler on 28 July 1944:

a. "The production curve shows clearly how after each decline as a result of enemy attack a rise again manifests itself, since under your leadership and support each time the bearings industry has been in the position to overcome the drops brought about by attack. Nevertheless the production has not sufficed to satisfy demand. Balancing has been achieved, aside from the constantly decreasing imports, by measures of the SRW:

(1) Mobilization of stocks of bearings in industry and in the Wehrmacht.

(2) Balancing of stocks and current orders by the cooperating industry committees.

(3) Moderation of the "Vorlauf" (See Para 3 below).

(4) Reduction of demand figures by scaling program needs down to actual needs, and by placing replacement requirements on a standard and reasonable basis.

(5) Replacement of bearings of complex construction with bearings of simpler construction."

b. These were obviously all emergency measures, since their total effect is to reduce the reserves of the whole economy rather than to increase the supply output. Their machinery was as follows:

(1) The "Mobilization of Bearings Reserves" program was originally planned as a quarterly survey, but was later made semi-annual because of the tremendous task of compiling reports from about 10,000 firms. The task was decentralized to a certain extent by placing the responsibility with the Gau Chambers of Commerce Industrial Departments, to each of which an expert from the bearings industry was assigned to do the actual compiling. From the reports were determined the inventories of bearings beyond the current needs; specifically, beyond the amount needs during the coming three to six months depending on the production cycle of each plant. These excess bearings were confiscated by the SRW and used to meet urgent needs. Stocks adequate for less than the normal six months' supply might be taken over to break specific bottlenecks.

(2) Within each industry, the committee was encouraged to balance the stocks of its members. In August, 1944, this "internal equalizing" was placed under the supervision of the bearings experts at Gauwirtschaftskammers (Regional Chamber of Commerce).

(3) The Vorlauf, the period from shipment of finished bearings until shipment of finished equipment was necessarily cut down with these inroads on normal stockpiles. Normally about three months, it was generally reduced, and for some Engpass types became a matter of days. Special couriers occasionally picked up bearings at the manufacturer and rushed them direct to the assembly line. In order to avoid such hand-to-mouth delivery, an Engpass commissioner had been appointed in November 1943 to supervise production of types in which such tightness seemed likely. In May 1944 it was necessary to introduce a special report from firms who foresaw exhaustion of their supplies. This was the Einbruchsmeldung ("Advice of Interruption") which was to be submitted by firms whose supply of a certain type of bearing would be used up within two weeks with no certainty of new delivery of bearings. By the end of 1944, about four to five hundred of these warning notices had been received. Many could be satisfied from stocks on hand, and in many more cases bearings were actually on the way but had not arrived. In the remaining instances, it was necessary either to substitute a less efficient bearing of the same size group, or rush through production regardless of routing schedules in the factory, which normally called for a three months' production cycle. At FAG, for example, a type could be run through in eight to ten days in an emergency, though at greatly increased direct and indirect cost.

(4) As part of the standardization program begun in the 1930s the number of types of bearings was reduced and bearings were grouped in accordance with their outer dimensions. The reduction in types meant a considerable saving in efficiency of production; whereas in in 1938 FAG was making 800 to 1,000 types each month, in the summer of 1944 it was producing only 250-3000 types. The grouping meant that if supplies of a bearing ran out, a quick substitution could be made of another type within the same dimensions that could be less efficient but would not require redesign.

24. In order to keep down the number of types and insure use of the most economically produced bearings, an advisory staff of technical experts was set up, with one engineer assigned to each Main Committee or important sub-group to advise in the preparation of new designs and encourage substitution both of simpler anti-friction bearings and of plain bearings. These same men worked with experts of the Sonderring Gleitlager ("Special Committee on Plain Bearings") to see that anti-friction bearings were replaced with plain bearings wherever the latter were available and technically suitable.

25. In general, these measures were taken on the basis of ordinances from Speer's ministry. The SRW had the authority to enforce its orders, but no cases have been found in which it had to bring suit to achieve its ends. Instead, it worked through consultation and agreement. Friction could thus be avoided, and in addition red tape could be kept to a minimum. Because of the constantly changing situation both in demand and supply, it was impossible for the SRW to keep fully informed of the position of manufacturers and consumers of bearings through formal periodic reports. After the July 1944 raids it had to reorganize and correct its whole card system of checking orders and work-in-progress.

26. To keep in touch with thesituation, meetings in which representatives of the bearings firms and their customers were brought together under the chairmanship of Kessler or an aide where instituted in the middle of 1944. At each meeting, the next four months' prospects for deliveries to tank, aircraft or ship manufacturers were canvassed, and arrangements were made to cover the most pressing demand. A typical meeting was that with members of Kraftfahrzeug (motor vehicle) firms in Hassfurt, on 24 June 1944. Needs for the remainder of June and for July andAugust were examined, the truck manufacturers presenting the bearings types in which delivery was uncertain, and thebearings firms agreeing on the measures to be taken. The following solutions were found, in rough order of importance:

a. Delivery from stocks of bearings firms
b. Delivery from stocks of other motor vehicle firms
c. Transfer of order from one bearings firm to another
d. Substitution of another type for that stipulated
e. Delivery from imports
f. Refusal of bearings to less important consumers
g. Delayed delivery
h. Loan of machinery from one bearings plant to another
i. Shipment of components from one bearings firm to another for assembly
j. Subcontracting rings to motor vehicle firms.

The remaining types were handed over to the Engpass commission. Becker writes in summarizing the meeting:

> "On the whole, it can be said that the bearings for June, July and August assembly can be furnished, under the assumption that the bearings firms hold punctually to the promises given, and that it proves possible to avert the Engpass in those few types that have been stressed."

Such in general were the procedures and results of the meetings with representatives of other industries.

27. The SRW had comparatively few dealings with other agencies in industry, government, or the armed forces. Kessler handled most of the negotiations with such organizations; the SRW dealt mainly with its member firms and with the committees representing their customers. Monthly reports of output went to Speer. At the end of 1944, meetings with other industrial agencies and with Berlin authorities became more frequent, chiefly in connection with special programs and with the attempt to substitute plain bearings for anti-friction bearings on a large scale.

28. The November 1944 reorganization of the Speer ministry made no practical difference in the Ring's functioning. The announcement of the Rustungsnotprogram (Emergency Armaments Program) in January 1945 did make a difference, however, since the emphasis thrown by that program on certain items of front-line equipment disrupted the SRW's production plans for the year. Its first measure was to set up a "Red List" of bearings types that absolutely had to be produced regardless of earlier production schedules or priorities. Since this threw the whole production scheme out of line, it had to be followed by an order permitting the firms to deal directly with customers on all types of equipment not coming under the Rustungsnot program and to supply them only after the bearings in the "Red List" had been produced.

PART THREE EVALUATION OF THE ATTACKS AND OF THE TARGET SYSTEM X

Evaluation of the Attacks

1. Bombing of the German anti-friction bearings industry between August 1943 and December 1944 was accompanied by a decline in production to half the pre-raid level in April 1944. By September the pre-raid level had been reattained, but bearings production in 1944 was only 83 per cent of that in 1943. The production loss thus amounts to the equivalent of two months' production in 1944, a slight loss at the end of 1943 and the drop at the beginning of 1945, when added in, raise the total loss to between two and three months' production at pre-raid levels.

2. The bomber offensive also prevented the industry from achieving its planned expansion. The planning was realistic and not merely hopeful, and thus represents a genuine loss; machines were on order and sites under construction at the time of the August raid. The machines and men were later actually fed into the industry; the approximately 13,000 machines in production in 1943 became 21,000 at the end of 1944 despite the destruction of at least 1,600. The 35,000 employees had become 48,000; and the 5.5 million sq ft of productive floor space had become 6 million despite destruction of 2.5 million sq ft by bombs. These resources, if unhampered in their utilization by constant attack, could have made the expansion program a reality.

3. That was the achievement of the combined bomber offensive. The achievement of the Germans was that they prevented this loss of output from delaying or halting armament production. By redesign of equipment and by substitution, they even prevented their armament production planning from being limited or revised because of failure of the bearings expansion program. As a result, the bombing of the anti-friction bearings industry, which had been intended to hinder production first of aircraft and second of other implements of war, failed to achieve that purpose.

The Allied expectations of the results of a reduced supply of bearings and of a reduced quality were defeated in the following manner.

a. Reduced Supply of Bearings

4. Through administrative measures: control of stocks, of orders and of deliveries; through production measures: rationalization, reduction of the pipeline, pooling of techniques and machine designs; and through protective measures: dispersal, bombproofing underground plants. Through all these measures production was restored after each raid and armament manufacturers were supplied with the needed bearings during the recuperation period.

5. The emergency measures - eating into stocks in hand of consumers and producers, and particularly reduction of the pipeline- did not permanently reduce the ability of the industry to meet the demands made on it. During the first half of 1944 and through the heavy July 1944 raids, the industry was living off fat in a way that could not be continued indefinitely, but with the completion of the dispersal program and the rise in output, a more nearly normal schedule was restored. Stocks in the hands of producers and consumers were built up, so that they were found to be normal during the field investigation in April and May 1945. The exceptions were, of course, bearings for new models in tanks and weapons, where the ordinary production cycle had to be telescoped and stocks could not be accumulated, and shortages where assembly or delivery had been prevented by transport difficulties.

6. The task of the bearings industry was somewhat eased by shifts in demand as well as by redesign. Abandonment of the German bomber program in1944 reduced demand per plane trememdously, for a bomber has used 1,000 bearings in contrast to 150 for a fighter. At the same time, to balance the increase in the number of fighter planes came the shift to jet-propelled craft in which the critical medium-bearings for motors, for which substitution had proved difficult, were no longer needed.

7. The other major armaments program, the tank program, which absorbed the bulk of the scarce medium-bearings, was also helped indirectly by a shift in demand. The motor vehicle industry was the main competitior for allotments of medium bearings. Its demand based on its planned production had been fully satisfiedin the first half of 1944, but output had fallen considerable below planned levels. Thus, to supply theincreasing tank output of the second half of 1944, deliveries to the motor vehicle industry were cut down drastically, since the latter industry still had on hand the unused bearings delivered to it in the first half of the year.

b. Reduced quality

8. In general, quality was maintained despite raid conditions by means of increased effort and slightly lowered output per worker. Inspection standards were maintained, according to the testimony of German technicians and the observation of American experts.

9. Within the approved standards, however, there was a considerable range of acceptance; and there is no doubt that at the end of 1944 in the effort to keep up the quantity of output themachine operators worked toward the extreme limits of tolerance and inspectors accepted marginal bearings. Certain refinements of finish- grinding of all surfaces and polishing of races- were cut down, partly because of haste, partly to husband the supply of grinding wheels and machine time,

partly through inexperienced labor and lack of supervisory force.

10. As early as 1942, the expanded demand for steel for bearings put a burden on steel mills that resulted in an inferior quality in steel, particularly in ball wire. Bearings failures were a consequence; these were not attributable to bombing, however, and were corrected after a few months.

11. A certain amount of relaxation in quality in an emergency war effort was no unwarranted; the test was whether the reduced quality led to inefficient performances. Testimony of German aircraft manufacturers and study of the performance of German arms revealed no evidence of abnormal number of bearings failures. Until cases of resulting failure of equipment are adduced, such lowering of quality as occurred must be considered unimportant.

12. The conclusion is similar in considering the substitution of plain bearings for anti-friction bearings. Substitution was not indiscriminate but depended on approval of new designs by the armaments delivery office of the Speer ministry, and the weapons testing office of the Army, which consistently turned down proposed substitute bearings for tanks. In the cases in which substitution was approved, particularly for airframes and guns, theoriginal use of anti-friction bearings was considered a luxury of design in most cases by German engineers. Variations in bearings quality affect only the last five per cent of performance of a plane, to use the figure of one expert; thus, though it is hard to determine with assurance whether substitution makes any difference at all in performance and how great that difference may be, it can be seen that the effect cannot be great. In critical movements, however, the last five per cent of performance and maneuverability may be decisive; hence, if evidence can be found that German planes and other arms were thus deficient andowed their deficiency to inferior bearings, an important result of attacks on the bearings industry would be estabilished. German armaments designers expressed satisfaction with the performance of substitute bearings, and no evidence of unsatisfactory performance has been found.

13. To the general conclusion that quality of German anti-friction bearings was sufficiently high even after the bombing, one qualification must be made. The German industry, though surpassed only by the United States and Sweden in quality and efficiency, never made the highest precision bearings. Shortages of bearings of this type, discovered particularly among precision instruments manufacturers, are thus not a wartime condition of a result of the bomber offensive.

14. The effort thrown by the Germans into their counter-measures indicates the importance they attached to the bearings industry. Nor can there be any doubt of their fright at the first attacks, particularly

the raid of October 1943; testimony of Speer and his associates and of the bearings executives, and the extreme administrative and technical measures taken prove that. The rapidity of redesign and substitution, the extent of reconstruction and repair, and the efficiency of administrative controls overcame the initial crisis, and from then on the Germans proceeded with more confidence. Indeed, Director Juergensmeyer when first interviewed spoke of the attack period as a "Wettkampf" (contest) in which the Allies were always the challengers, but never a serious threat. By April 1944, the Germans were confident enough to resume plans for doubling output. The July raids temporarily shook them, since the Ebelsbach attacks were thought a portent of a series of attacks on undefended dispersal points, but this fear proved groundless. The next test was the cessation of imports from Sweden in October 1944. The problem had been foreseen, however, and the "Ohne Hilfe" (Without aid) program had been instituted to balance this loss. The outcome of the whole struggle was stated succinctly by Colonel Stamm at a meeting of Speer's Armament Staff in December 1944: "No equipment has been held up by lack of bearings!

15. In retrospect, the initial fright of the Germans and our high initial hopes seem justified. The tactical advantages on our side were as obvious to the Germans as to us, and their resources of stocks, technical skill, and equipmentwere hardly any better realized by them than by us.

16. Our prime initial advantage was the concentration of German bearings production and our exact knowledge of the location and importance of all major plants. An accompanying advantage was the unprotected exposure to attack of the factories; there was almost no bombproofing or erection of blast walls; air- raid shelters were inadequate, utilities conduits were exposed or without alternate channels, old wooden buildings constituted fire hazards. Our expectations of the effectiveness of precision bombing were still high. The following comment on the October 1943 raid by General LeMay, then Commanding General of the Third Bomb Division, illustrates what was thought possible:

"All crews have again been impressed with the importance of making every possible effort to complete the destruction of each target of the first attempt, making it unnecessary to return later. The record shows the cost in crews and aircraft is always less on theinitial attack."

17. The Germans in turn had certain compensating factors in their favor. The swollen stocks in the hands of end-items producers constituted the first. The lavish use of high quality bearings in equipment design was the second, with its resultant possibilities for reduced demand through substitution and redesign. Finally, the advanced stage

of the expansion program provided machine tools ready to be set up in place of those destroyed, with minimum loss of production time.

18. Our chance for complete success thus depended on exploiting our special advantage and wiping out the main productive centers before they could be moved or protected. The Germans had the problem of feeding current armament production from stocks until facilities could be dispersed, disguised, and protected and until demand could be cut down by redesign and substitution. Unfortunately, no definite test of the two possibilities was made in 1943, since operational limitations kept the Allied air forces from pressing home their attack with the planned weight. Given a reprieve by the four months lull between October and February, the Germans were able to anticipate and evade our future blows. Saur, Speer's deputy, claims that the industry, helped by the available stocks, could have recovered with almost equal success had it been devastated in the fall of 1943, but his claim must remain mere hypothesis.

Evaluation of the Basic Target System

19. The inconclusiveness of the 1943 attacks, because of the unexpectedly easy supply situation in Germany and Allied inability to exploit advantages, has left many who consider the anti-friction bearings industry a basic target. Speer, for example, when questioned as to "a better and more effective air offensive plan", suggested the bearings industry:

"....only by concentration on targets which eliminate a cross-section factor of the industry is quicker success possible. Hereby the succession of attacks must be accelerated in order to make reconstruction impossible. The destruction of the ball bearings industry could have been effected with the least expense and would have resulted in a complete breakdown of our production after four months, and even after two or eight weeks in important sectors."

Speer's reasoning is essentially the same as that which led to the selection of the industry as a target in 1943. The basic question is: Does the bearings industry satisfy the requirements of a good basic target? The evidence pertaining to that general question can be sifted out of the data of the German story, by eliminating the special circumstances in Germany.

20. The requirements for a basic target, stated in our first chapter, may be summarized as follows:

We must know the location of the industry's plants and the concentration, so that we will know how many plants and which ones need to be destroyed to cripple the industry. We must know how effective physically we can expect our attacks to be- how much damage will be

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inflicted on the equipment, stocks, and plant facilities by our bombs; in a word, we must know the vulnerability of the plants. We must know how the damage to the target industry will affect the enemy; first, the time he will have before the effects are felt in the front lines- the depth of the target industry; and second, the number of alternate ways of absorbing the effects- the cushion, whether of stocks to repalce current production in excess of demand that will not be missed, of unused capacity that can be brought into play, of technical skill that will devise substitutes for destroyed materials, processes, and products. We must know the recuperability of the industry- the length of time required to repair plants, machines, instruments; and the availability of the men, materials, and facilities for carrying out the repair and replacement. Lastly, we must know the mobility and adaptability ofthe industry- the degree to which it can flee the known centers of production and be carriedon under irregular conditions of production.

Location

21. The first lesson of the German experience is the indispensability of adequate and firm economic intelligence on the location and output of plants. The Allies knew exactly the anatomy of the industry in 1943 and early 1944, and their attacks on 90-95 per cent of the facilities were responsible for a 50 per cent drop in production by April 1944. By October 1944 the factories we considered worth attacking represented only 20 per cent of the industry's output, and bombing had little effect. In July we had known of only one dispersal plant, andwe had falsely identified the product of that one. In early 1945 we knew the names of a dozen dispersal sites, but confused store-rooms with productive units, major factories with minor ones, assembly points with machine shops; and we were deceived by the false names used by the enemy for his new plants. This ignorance is perhaps excusable; a bearings plant has few, if any, physical characteristics recognizable from the air, and when put into a converted textile or stone-working plant or underground facilities, cannot be identified. The importance of ground intelligence intercepts; interrogations must therefore be emphasized. They furnish the alternate source of information on the essential prerequisite of attack; knowledge of the location and relative importance of the targets, with which attack will be merely indiscriminate.

Vulnerability

22. Because of the concentration of tools, instruments, and equipment in a bearings factory, the damage done by bombs will be considerable. The industry is physically not notably more vulnerable to attack than most industries, however. As was pointed out in Chapter III, the

most effective single raids resulted in destruction of no more than 12 per cent of machine tools, while the whole series of raids destroyed at best 10-15 per cent of the industry's machine tool inventory. Other damage to instruments and equipment was proportionate; damage to stocks of materials was slight, and damage to stocks of finished product was limited by the transport system, which facilitated a policy of immediate shipment of finished bearings to depots. Undoubtedly, intensified attack and more effective bombs would increase the extent of damage; but not in a way peculiar to this industry. In the bearings industry as in others, blast walls and partitions, shields against dust and debris for machine tools, bomb-proof walls and roofs and other physical measures of protection proved effective in reducing damage.

Cushion

23. In regard to the cushion, as in regard to location, there will be great differences in various countries, and the importance of reliable economic intelligence must be emphasized. The consumer's stocks, the lavish use of bearings in design, the expanding capacity that stood Germany in such good stead, need not be present. The German experience does underline their significance, however. Since the recuperation cycle is so short, the availability of stocks and other resources means time for recovery without interference with end-item production. It should also be noted that the German story does not fully test the possibilities of substitution; despite the great skill shown by the Germans in carrying through the substitution program efficiently in a short time and under stress, there remained many places where the Germans believed that demand for anti-friction bearings could have been further reduced over a longer period or with foresight. Clearly, studies of captured enemy equipment should build up a careful chronological knowledge of the enemy's use of bearings and of any changes in design that would imply shortages. Inferences of shortage would seem justified in instances in which plain bearings of definitely inferior performance are substituted for anti-friction bearings; and an inference merely of cautious foresight in cutting down consumption should be drawn from substitutions which do not materially reduce performance levels.

Depth

24. The pipeline between bearings plant and battlefront is also a variable factor. There is a minimum, however, for each type of equipment, averaging about three months. The German experience shows clearly on the one hand how stocks can extend the pipeline, and on the other how production, delivery and installation of bearings can be accelerated to cut down the pipeline when necessary. Thus, intelligence on the enemy's economy is once more essential. With a normal or long pipeline, time for recuperation is allowed without interference with armaments production; with a short one, either as a policy of production planning or

because of tightness in supplies, damage to bearings production will be reflected in end-item production however quick recuperation may be.

Recuperation

25. The German experience shows how rapidly recovery of a bearings plant can be achieved. Four months were adequate for restoration of productive levels after the most severe raids, and the period was correspondingly brief when damage was less severe. Damaged machine tools were repaired usually within two months and almost always within three, while the maximum construction time for replacement machines was four months. Plant could be either rebuilt within the same span (or in departments where the labor force could even work without roofs), or facilities from textile or other factories could be converted.

26. Recuperation depended on the resources of the whole economy as well as on the nature of the bearings industry specifically. With men, materials, and excess plant capacity made available, recuperation could be achieved well within the margin of time allowed by the depth of the industry and to the reduced level enabled by the cushion. The industry, so indispensable to armament production, does not loom proportionately large when its share of the resources of an economy is analysed. To take the German example, its working force is but one-half of one per cent of those employed in mining and manufacture; its machine tool inventory is one per cent of the national stock and 10 per cent of the yearly construction; it uses only ten to fifteen thousand tons of steel monthly. So insignificant a segment cannot constitute a major drain on the economy even if completely rebuilt; and when it is so indispensable as is assumed in its selection as a basic target, it will have the priority to enable rebuilding- as happened in Germany in the fall of 1943.

Mobility and Adaptability

27. The bearings industry, by the nature of its productive methods, is well adapted to decentralized production and presents no serious obstacles to underground operations. It can thus break up into so many small units that a bombing offensive will be extremely difficult even when the plants are discovered, and these units can be almost completely protected from bomb damage.

28. As Schieber of the Speer Ministry put it, the concentration of the German bearings industry at Schweinfurt was an "historical accident." There were commercial and technical advantages for the major firms, but these were not major. Almost any kind of plant facility was suitable for bearings manufacture; apart from supervisors and a few of the most highly skilledworkers, labor could be quickly trained; and the finished bearings presented no transport problem.

In addition, the production of the various components, carried out in separate departments even in a central plant, could be easily dispersed to separate sites. A slight increase in costs would result, but one trivial compared with the decrease in vulnerability. For underground operation, the only major problem was air-conditioning, and this proved soluble at Neckarzimmern, Linz, Ruedersdorf, and other sites.

General

29. The special circumstances under which attack on the bearings industry can be expected to achieve decisive results are thus four; Exact knowledge of the location of the plants, absence of a cushion that would absorb the impact of bomb damage before it affected armament production, a general tightness in the enemy's capital goods situation to hinder rapid recovery, and a sufficient striking force virtually to obliterate the industry by heavy and repeated attack without allowing time for recovery.

30. If several of these conditions do not apply, then (as in Germany) no significant results can be expected; if any one of them does not apply, success will be only partial, since the adaptability of the industry to aboveground and underground dispersal and its capacity for recovery will enable it to escape from the effects of attack and be rebuilt where the rewards of attack will be scant.

INDEX OF REFERENCE NOTES

The following are notes describing reference items forming material upon which this report was based.

1. Kugelfischer Georg Schaefer Development (Kugelfischer Georg Schaefer Ausarbeitung) -- Contains historical sketch of growth of the Kugelfischer firm, in terms of buildings, machines and labor, and monthly statistics of production of bearings, by size and bearings components, Jan 1943 -- Mar 1945, for each plant.

2. Golden Book of Kugelfischer Records -- Contains historical and analytical data on Kugelfischer operations, and monthly statistics, 1943-1945, for each plant of employment, production and absenteeism.

3. Air Attacks on Kugelfischer Works (Luftangriffe auf die Kugelfischer Werke) -- Contains bomb plots and damage reports covering each raid on the Kugelfischer Schweinfurt and Ebelsbach plants, 1943 and 1944.

4. Ebelsbach -- Floor plans, bomb plots damage report employment statistics, absenteeism and work flow charts of the Ebelsbach dispersal plant, 1943 and 1944.

5. VKF Report Prepared for USSBS -- contains damage reports and bomb plots for each of the raids on the VKF Schweinfurt Works, 1943--1944.

6. Production and Demand (Leistung and Bedarf)- Statistics collected by the Sonderring Walzlager on total production and demand, anti-friction bearings, 1943-1944.

7. Production of the German Anti-friction Bearings Industry- (Ausbringung der Deutsche Walzlager Industrie- 1943) Monthly production statistics by firms for each bearing size range, 1943.

8. Production of the German Anti-friction Bearings Industry-1944. (Ausbringung der Deutsche Walzlager Industrie-1944). --Monthly production statistics by firms for each bearings size range, 1944.

9. Firm's Status (Firmen Ubersicht) - As of October 10, 1944, the number of employees, machines, and square meters of floor space for each firm in the Sonderring Walzlager.

10. Translations of SRW Documents -- Letters, circulars, and other documents of the Sonderring Walzlager, 1942-1945.

INDEX OF REFERENCE NOTES

11. SKW Employment Data - Monthly reports of employment in principal bearings firms, 1942-1944 by sex and skill.

12. Foreign Production and German Imports -- Kroner value of imports of bearings and bearings machinery from Sweden 1942-1944, and number of bearings imported from Sweden, Switzerland, Italy, and France, monthly, 1944.

13. Planned and Actual Production, 1943-1945 - (Soll und Ist Produktion, 1943-1945)-- Total production of bearings, desired and actual, by types and sizes, for each month Dec 43 - Jan 45.

14. Sales in Reichsmarks, 1943-44 (Umsatz in RM, 1943-44) Turnover or sales in RM for each bearings firm and total industry, monthly 1943 and 1944.

15. Demand Data SKW - Total bearings needed by each major user industry, December 1943 and first 6 months of 1945.

16. Per cent of Development of Production (Prozentual Anteil der Fertigung) - Indexes of production 1943-44 for each bearing firm, of bearings in all size ranges.

17. Demand, planned and actual production statistics and graphs, 2nd half 1944 (Bedarf Soll und Ist Leistung 2tes Halbjahr 1944.)

18. Demand, planned and actual production statistics and graphs, 1st half 1945 (Bedarf Soll und Ist Leistung 1 Halbjahr 1945.)

19. Plant Folders - Pertinent material, including intelligence reports, photographs, bomb plots, production statistics, reports of plant visits, etc: to the following plants -

a. Jaeger
b. DKF
c. Kling
d. Muller
e. VKF Stuttgart
f. Neckarzimmern
g. Wellen Cave
h. Demag Gleitlager
i. Fichtel
j. Deutsche Star Schweinfurt
k. Steyr

20. Card File of Members Firms Sonderring Walzlager - Name, Location, Type of Product and Capacity of Each Firm.

21. First Activity Report - Summaries of Activities of Government rings including Sonderring Walzlager (Erste Tatigkeitsbericht - Hauptrings Produktions - Mittel und Maschinenelemente, August 1942.)

INDEX OF REFERENCE NOTES

22. Monthly Compilations on Employment by Bearings Firms (Arbeitseinsatz Monatliche Zusammenstellungen)

23. Dispersals - (Verlagerungen) 1943 Plans for Dispersal

24. Plans for Expansion (Auswertungsplane) Allocated production goals for each firm by size ranges and types of bearings.

25. Bearings Piece Records (Stuckliste) Bearings requirements for various types of armament equipment per unit.

26. Guide Book (Sonderring Walzlager Bibel) List of Machine Tools ordered 1943 - 44, under expansion program.

27. Circular Letters (Rundschreiben) Basic decrees, statements of policy, and correspondence.

CONVERSION TABLE

WEIGHT

1 gram	0.035 ounce
1 kilogram	2.205 pounds
1 metric ton	1.102 tons (short) = 2,205 pounds

LENGTH

1 kilometer	0.621 mile = 1,094 yards = 3,281 feet
1 meter	1.09 yards = 3.28 feet = 39.37 inches
1 centimeter	0.3937 inch
1 millimeter	0.039 inch

AREA

1 square meter . . .	1.196 sq yds = 10.76 sq ft = 1,550 sq in
1 square centimeter.	0.155 square inch
1 square millimeter.	0.00155 square inch
1 hectare	2.471 acres = 11,960 square yards

VOLUME

1 cubic centimeter .	0.061 cubic inch
1 cubic meter	1.308 cub yds = 35.31 cub ft = 61,023 cu in

TEMPERATURE CONVERSION

Centigrade into Fahrenheit = multiply by 9/5 and add 32

A-1 - KUGELFISCHER BALL-BEARINGS PLANT - SCHWEINFURT - PRE-RAID

A-2 - KUGELFISCHER BALL-BEARINGS PLANT - SCHWEINFURT - POST-RAID

PHOTOGRAPHS 1-35

A-3 - VKF-I BEARINGS PLANT - SCHWEINFURT - PRE-RAID

A-4 - VKF-8 BEARINGS PLANT - SCHWEINFURT - POST-RAID

PHOTOGRAPHS 36-87

A-5 - VKF-II BEARINGS PLANT, SCHWEINFURT - PRE-RAID

A-6 - VKF-II BEARINGS PLANT, SCHWEINFURT - POST RAID

PHOTOGRAPHS 88-101

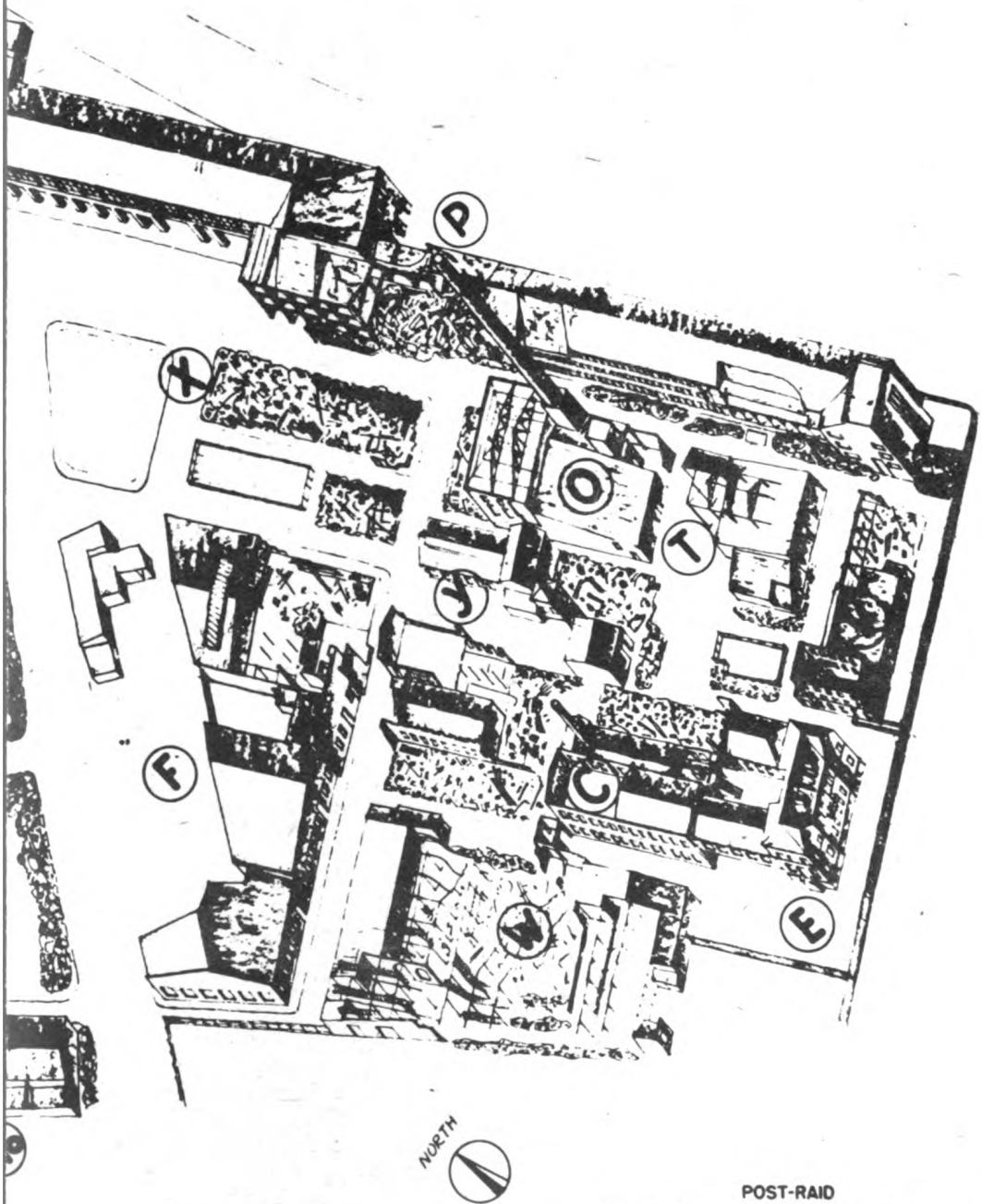
A-7 - PHOTOGRAPHS 102-111: BOMB DAMAGE - VKF-STUTTGART

A-1 PRE-RAID ISOMETRIC VIEW OF KUGELFISCHER BALL BEARING PLANT

A-2 POST-RAID ISOMETRIC VIEW OF KUGELFISCHER BALL BEARING PLANT

and

PHOTOGRAPHS 1 - 35



POST-RAID

US STRATEGIC BOMBING SURVEY
KUGELFISCHER
BALL BEARINGS PLANT
SCHWEINFURT BAVARIA
EXHIBIT A-2

Photo 1 - Aerial view at 500 ft. looking north showing overall damage to plant at time of capture.

Photo 2 - Aerial view at 100 ft. looking west showing damage at time of capture. Bldg. I at right. Bldgs. L and K in center.

Photo 3 - Bldg. P (office bldg.) before the raids.

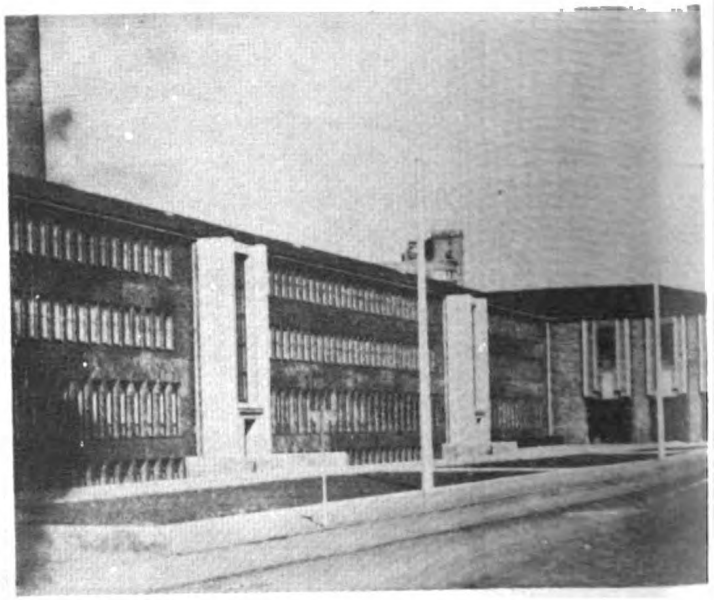


Photo 4 - Bldg. P (office bldg.) before the raids.

Photo 5 - Bldg. P - view showing office building on fire as result of IB's.

Photo 6 - Bldg. P - Interior of drafting room showing effects of fire on concrete frame structure resulting from raid 14 October 1943.

Photo 7 - Bldg. P - Interior view of office building showing effects of IB's of raid 17 August 1943 on concrete frame structure.

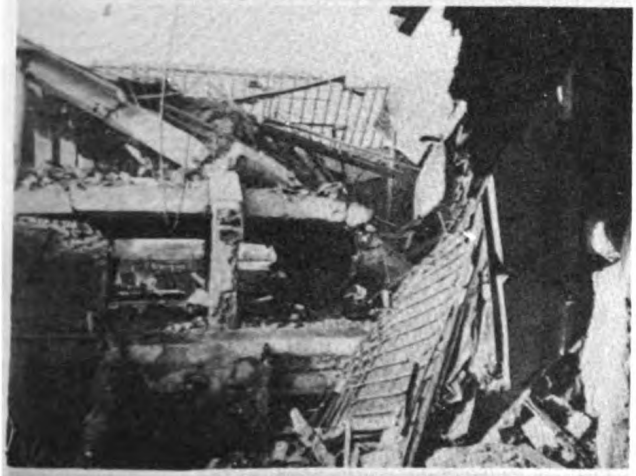


Photo 8 - Bldg. P - Damage to concrete frame structure resulting from HE's of raid 14 October 1943.

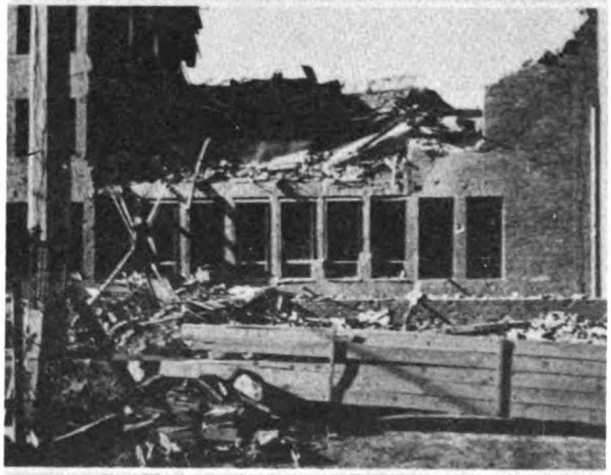


Photo 9 - Bldg. P - Blast and fragmentation damage to structure resulting from HE's of raid 14 October 1943.

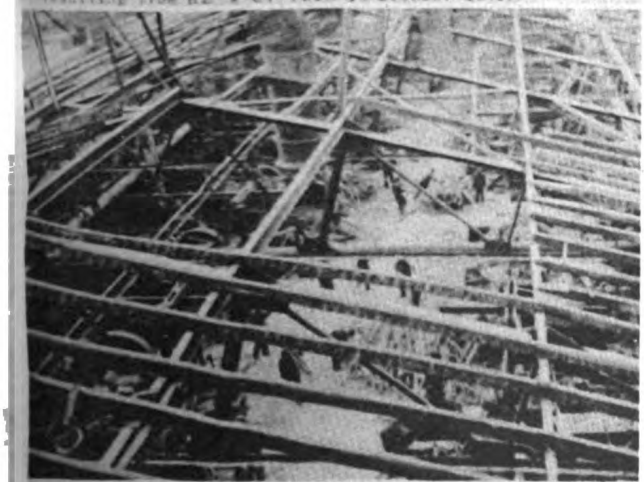


Photo 10 - Bldg. L (Forging Shop). View looking down showing blast and fragmentation damage to roof structure, slight damage to machines and equipment. Raid 14 October 1943.

Photo 11 - Bldg. L (Forging Shop). Blast and fragmentation damage to roof deck and curtain walls from one HE direct hit. Slight damage to machines and equipment. Raid 14 October 1943.

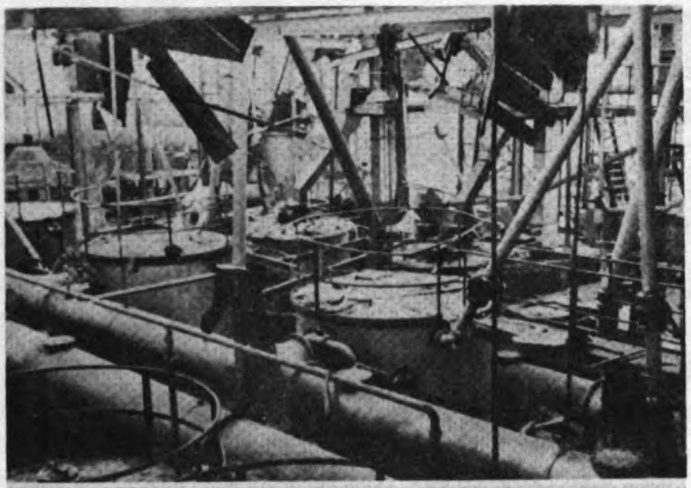


Photo 12 - View showing superficial damage to Bldg. K - gas generating building. Very little damage was sustained by the equipment.

Photo 13 - Bldg. G - Tempering Department hit by HE's. A steel frame structure with brick curtain walls was damaged structurally but very little damage was sustained by the equipment.

Photo 14 - Bldg. A - Superficial damage resulting from fire created by direct hit of HE bomb on underground oil storage in front of this building.

Photo 15 - Interior view - 5th floor of Bldg. A showing superficial fire damage.

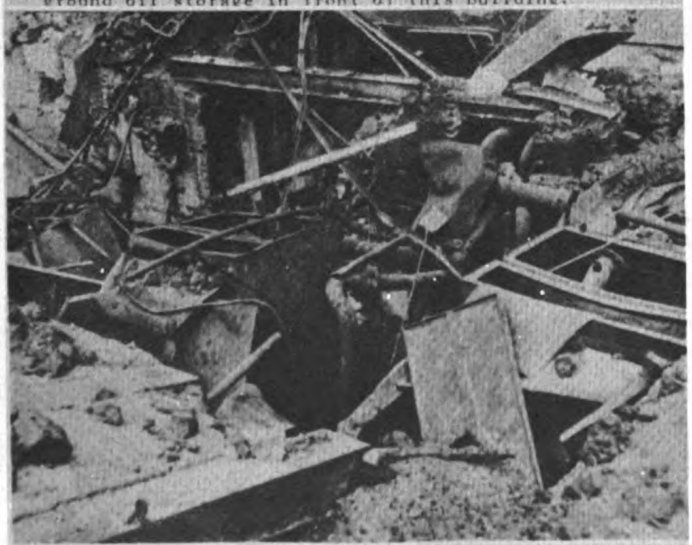


Photo 16 - Direct hit by HE bomb on underground petroleum storage tanks in front of Bldg. A, followed by one IB creating fire which spread to Bldg. A. Raid 14 October 1943.

Photo 17 - View of destroyed underground petroleum storage tanks in front of Bldg. A. Raid 14 October 1943.

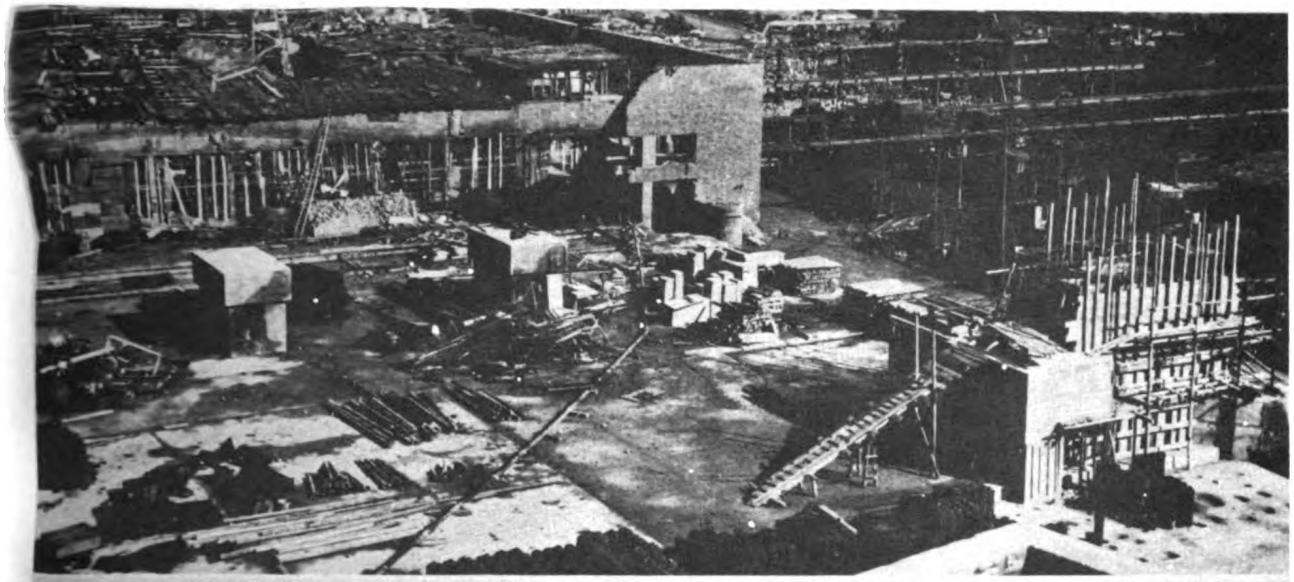


Photo 18 - View looking northwest - showing 8 ft. thick reinforced concrete roof slab with vent shafts. Note construction in progress to right, and disruptive pattern painting on vent shafts. Section of repaired Bldg. R in rear. Note unfinished stock piles.

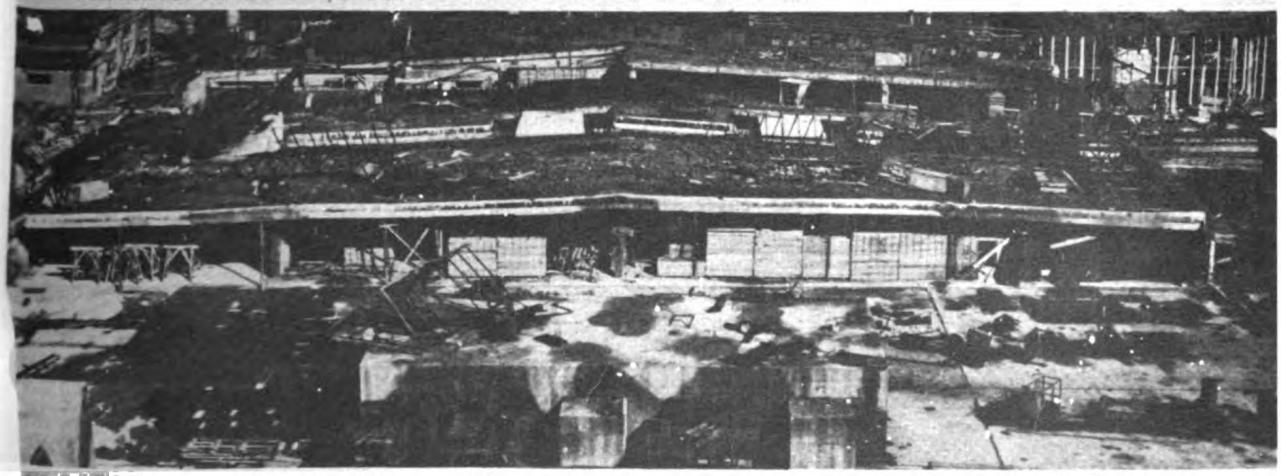


Photo 19 - View looking north - Taken from roof of undamaged section of Bldg. R. Note disruptive pattern painting on shafts and material piled about to distract attention.

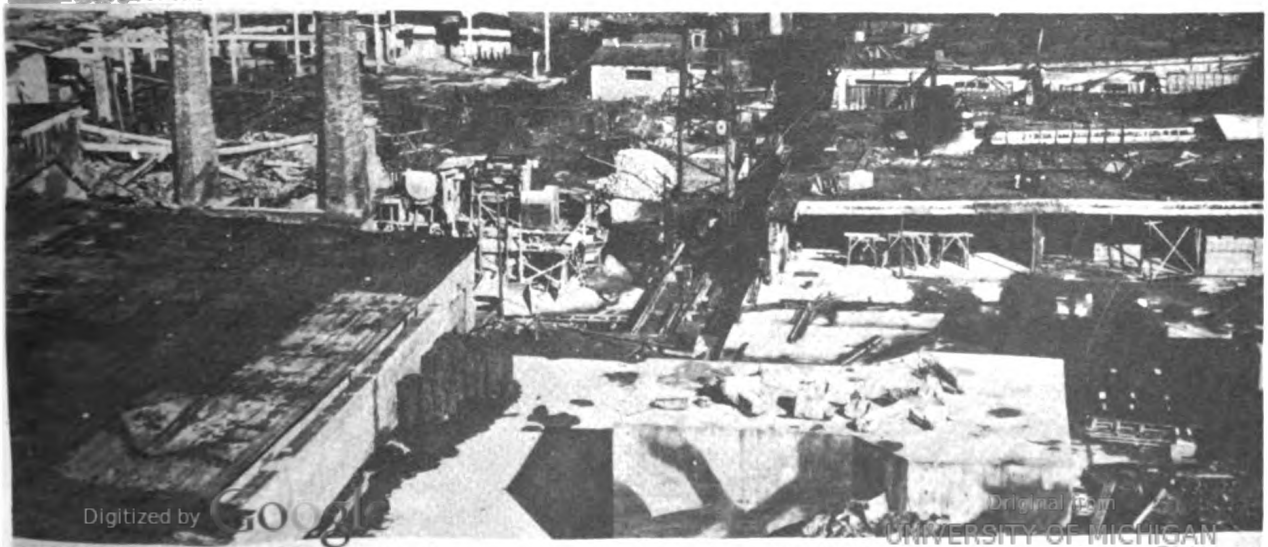


Photo 20 - View looking northeast - showing portions of Bldg. R still standing. Bldg.

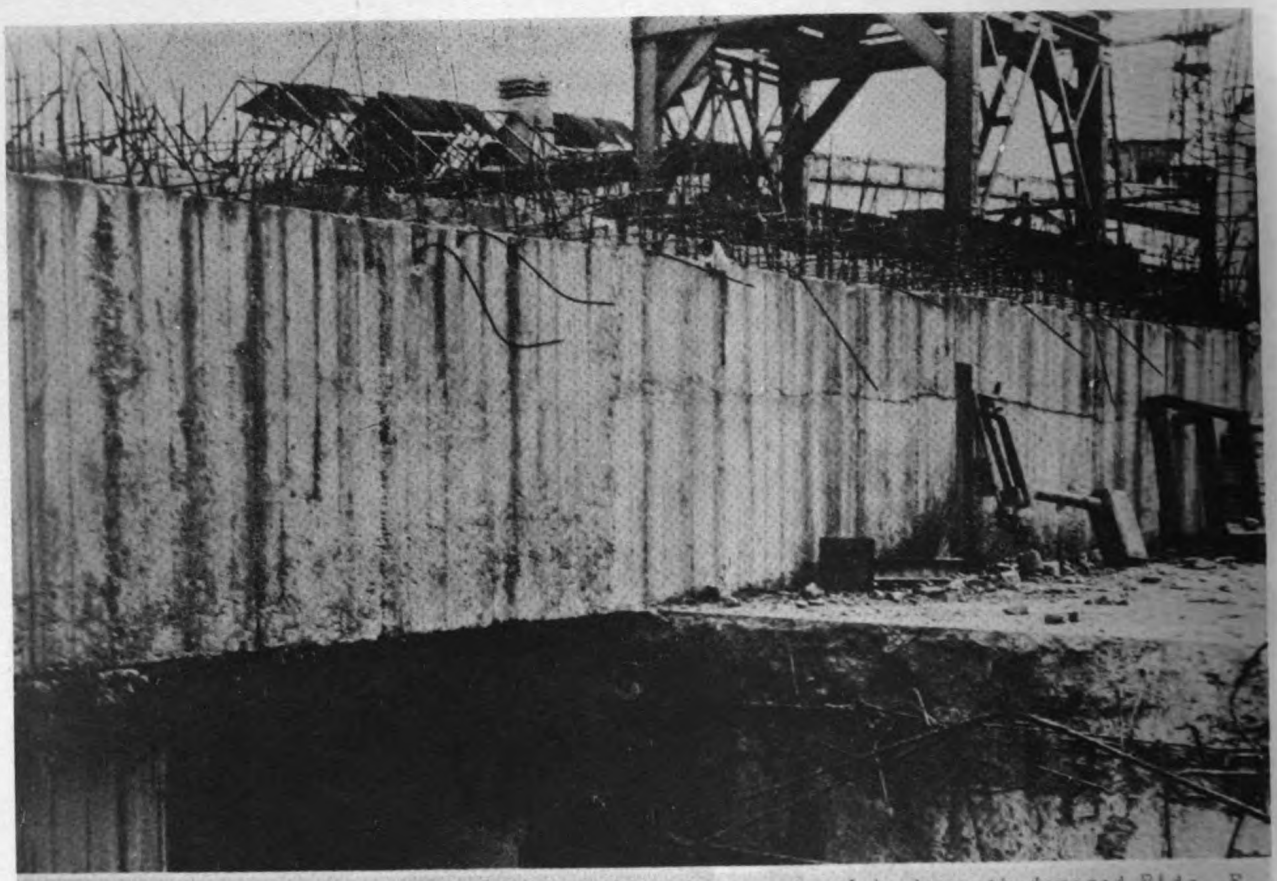


Photo 21 - Close-up of 8 ft. thick reinforced concrete slabs beneath damaged Bldg. K.

Photo 22 - Close-up of "cubical type" reinforcing used. This is similar to type used in concrete air raid shelter which sustained two direct HE hits of 1000-500 lbs. with superficial damage.

Photo 23 - Bldg. A - Aerial view of multi-story building at 400 ft. showing overall extent of damage at time of capture in April 1945. Note pattern painting on Bldg. F lower center.

Photo 24 - Bldg. A - Close-up aerial view at 300 ft. Note bricked-up openings and [illegible] resulting from earlier raids. Part of Bldg. F at lower right.

Photo 25 - Bldg. A - Close-up view of damage at time of capture. Photo taken from roof of Bldg. F looking northwest.

Photo 26 - Bldg. A - East end completely destroyed by direct hit.

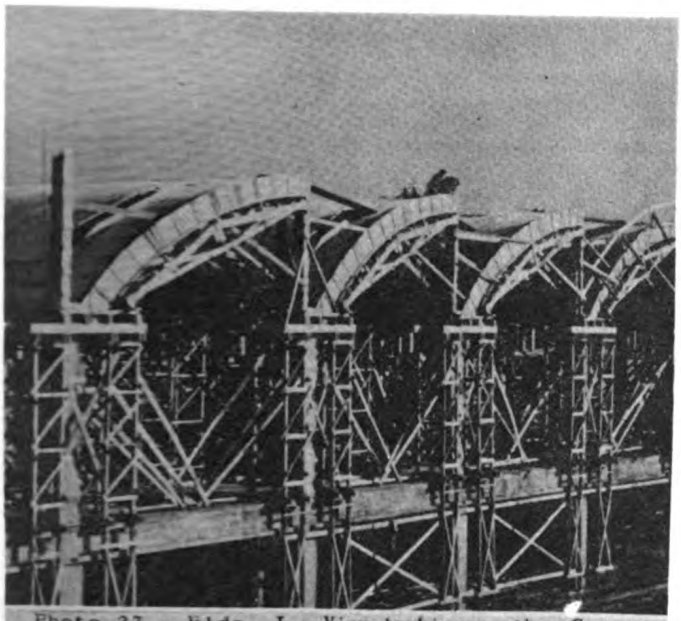


Photo 27 - Bldg. I - View looking north. Construction was completed in 1939. It is of concrete frame curtain walls. It has the curved type skylight.

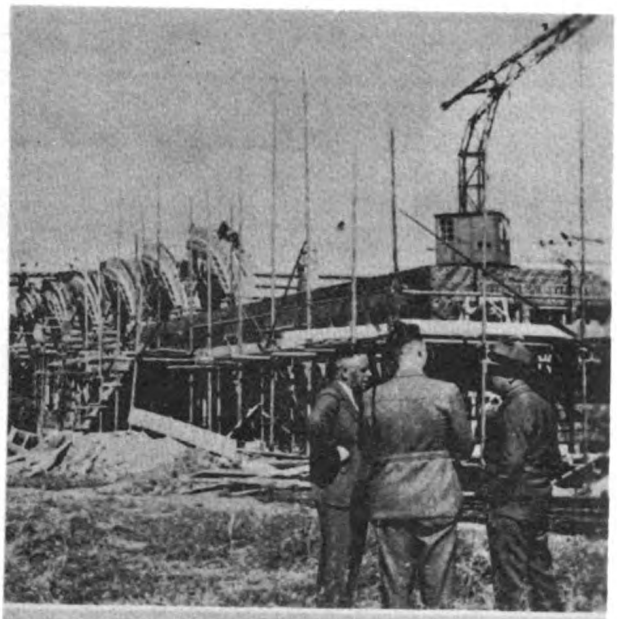


Photo 28 - Bldg. I - Under construction - View looking east.

Photo 29 - Bldg. I - At time of capture in April 1945. Aerial view at 300 ft. looking north. Damage resulting from a number of direct hits from HE's.

Photo 30 - Bldg. I - Close-up view - Showing extensive blast and earth shock damage due to HE's.

Photo 31 - Bldg. I - Collapse of section of concrete skylights due to destruction of concrete supporting frame by blast.

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Photo 32 - Bldg. I - Close-up of blast damage to supporting concrete framing members.

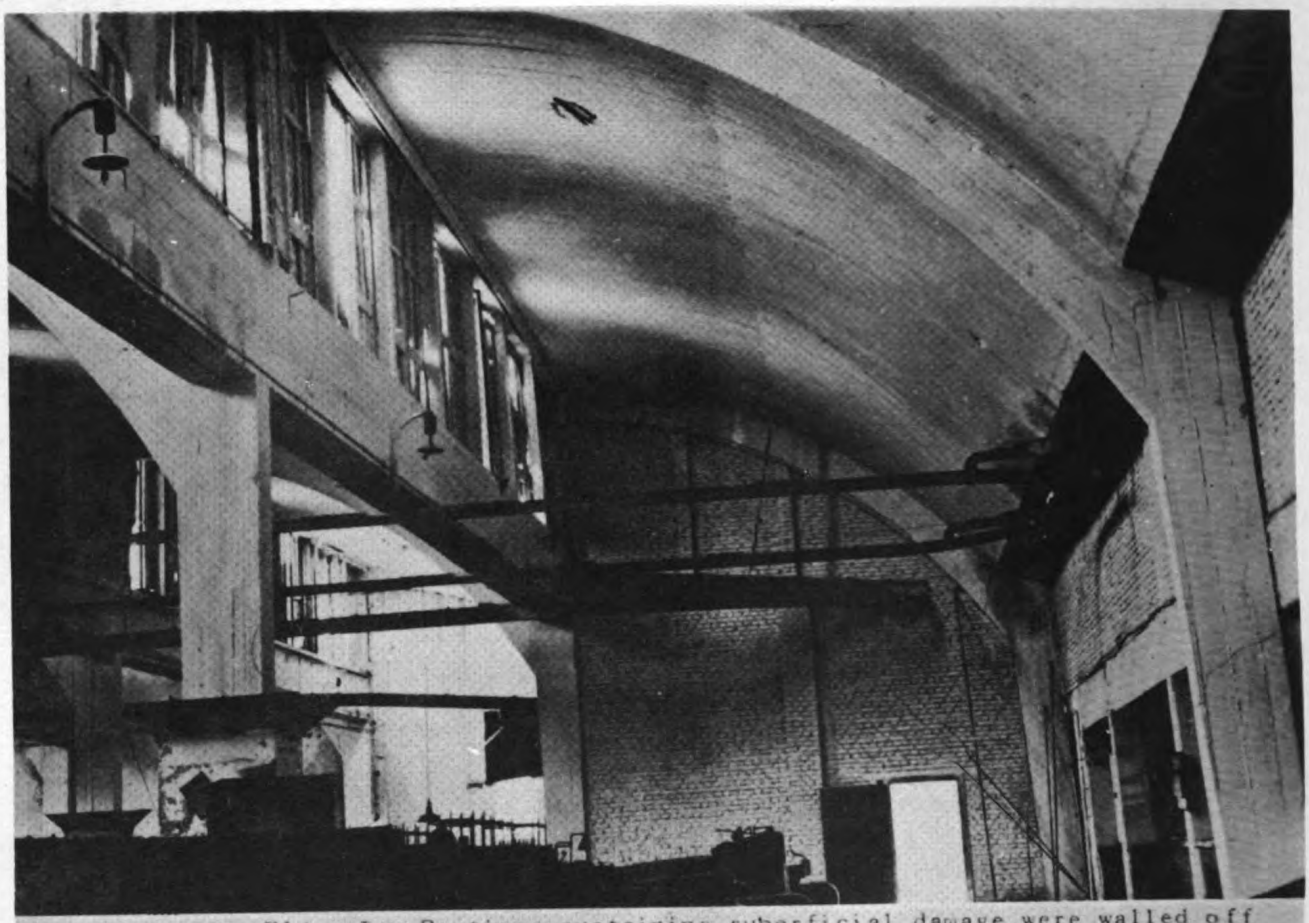

Photo 33 - Bldg. I - Portions sustaining superficial damage were walled off and repaired, with floor space reclaimed.

Photo 34 - Camouflage - Debris painting - Bldg. A - Elevator shaft at west end reconstructed. Debris painted as a concealment measure. Note "bricked-up" openings.

Photo 35 - Camouflage - Bldg. R - Disruptive painting to simulate building damage at entrance to underground structure.

A-3 PRE-RAID ISOMETRIC VIEW OF VKF I BEARINGS PLANT AT SCHWEINFURT, BAVARIA

A-4 POST-RAID ISOMETRIC VIEW OF VKF I BEARINGS PLANT AT SCHWEINFURT, BAVARIA

and

PHOTOGRAPHS 36 - 87

Photo 36 - Aerial view at 300 ft. looking east showing VKF I plant at time of capture, April 1945. Buildings 19, 20, 21 and 22 in center foreground. Building 43 right foreground.

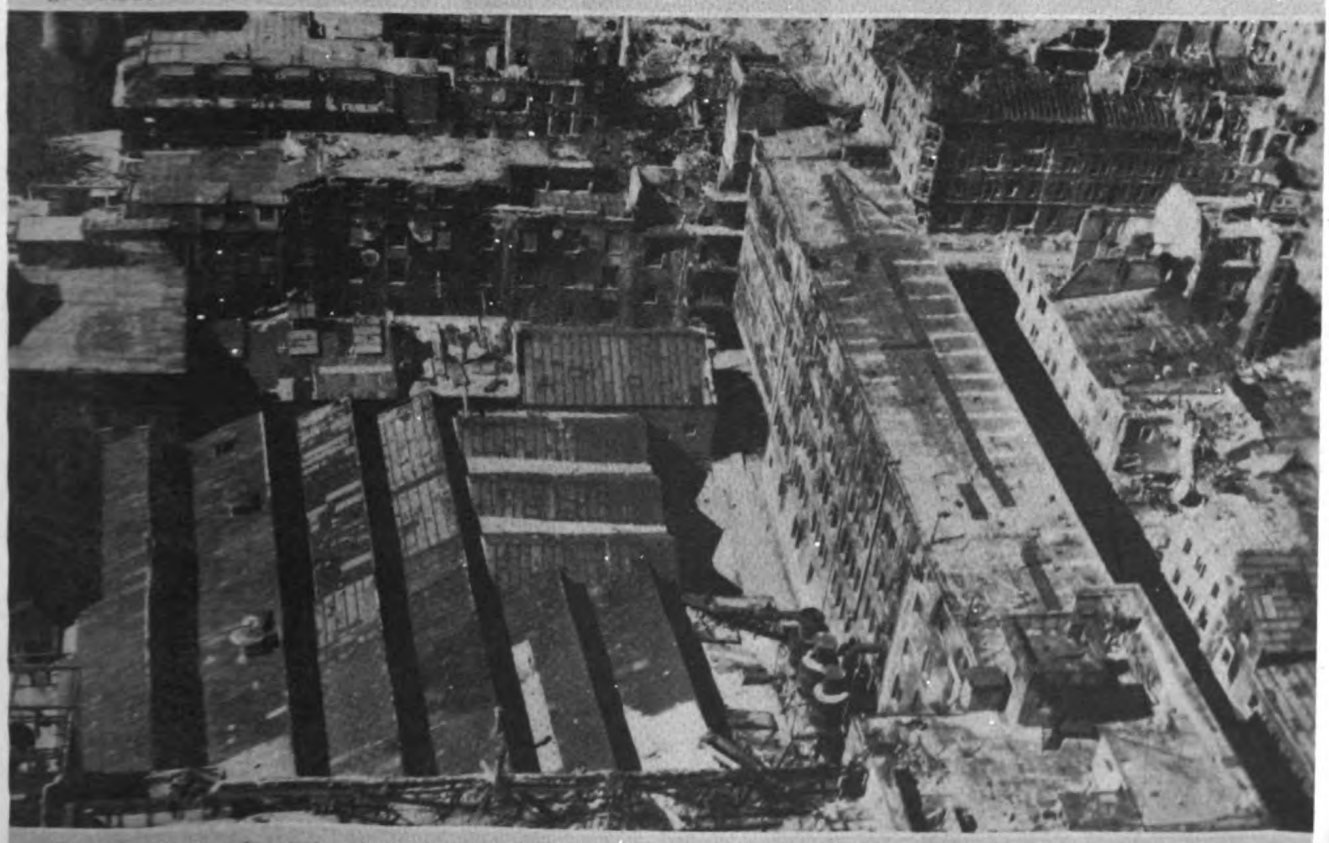

Photo 37 - Aerial view at 300 ft. looking west at time of capture, April 1945. Saw-tooth skylights of buildings 45, 47, 50 and 51, left foreground and building 42 to the right.

Photo 38 - Captured photo showing German firemen in action.

Photo 39 - Captured photo showing German firemen in action.

Photo 40 - Captured photo showing German firemen in action.

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Photo 41 - Captured photo showing damage to building 64 and connecting bridge between 64 and building 42.

Photo 42 - Captured photo showing damage to building 64 and connecting bridge between 64 and building 42.

Photo 43 - Captured photo showing damage to building 64 and connecting bridge between 64 and building 42.

Photo 44 - Captured photo showing fire and blast damage to building 42.

Photo 45 - Captured photo showing fire and blast damage to building 42.

Photo 46 - Captured photo showing fire and blast damage to building 42.

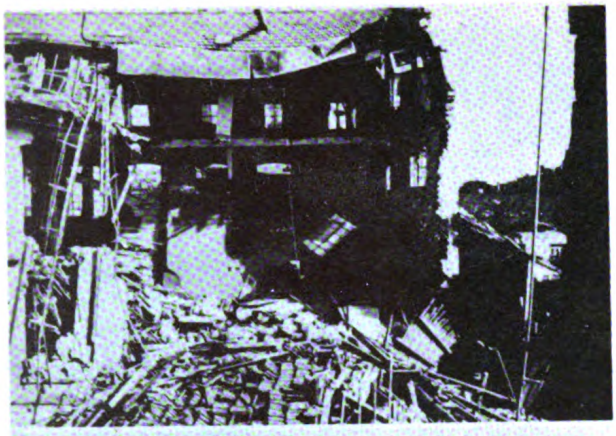


Photo 47

Photo 48

Photo 49.

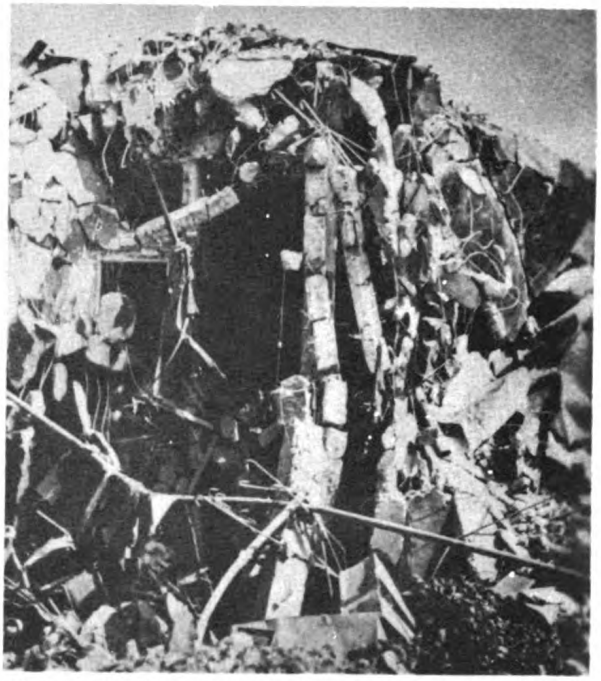
Photo 50.

T-2007

Photo 51

Photo 52.

Photos 47 to 52 - Captured photos showing blast and fire damage to unidentified buildings.



Photos 53 and 54 - [illegible] of [illegible] reinforced concrete structure of [illegible]

Photo 55.

Photo 56.

Photo 57.

Photo 58.

Photos 55 to 58 - Captured photographs of last stage to brick load-bearing structures.

Photo 59 - View of upper-stories of bldg. 43 damaged by fire.

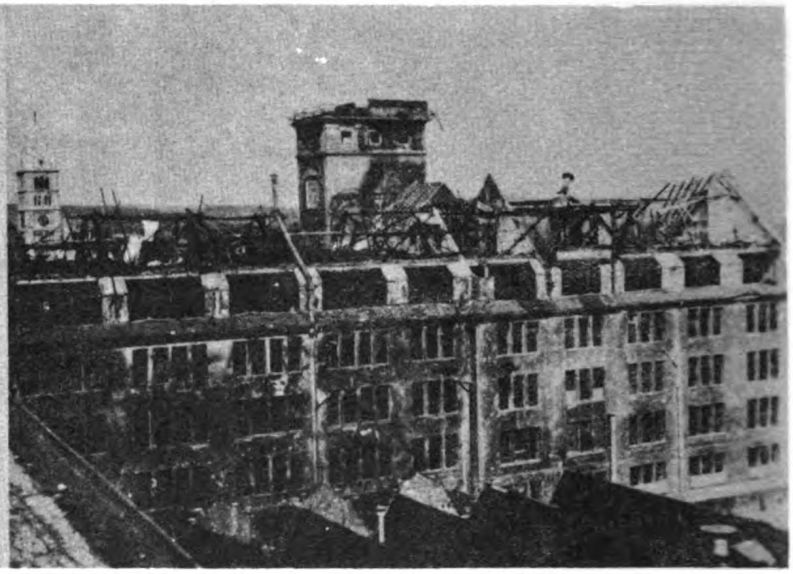


Photo 60 - Damage to reinforced concrete roof deck of building 41. Note corrugated steel sheets for roof repairs, of floor below.

Photo 61 - Blast damage to buildings 102 and 41.

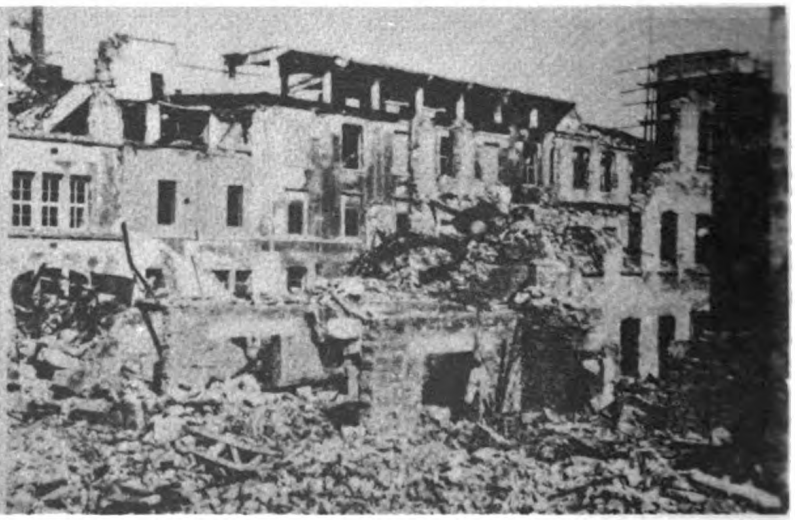
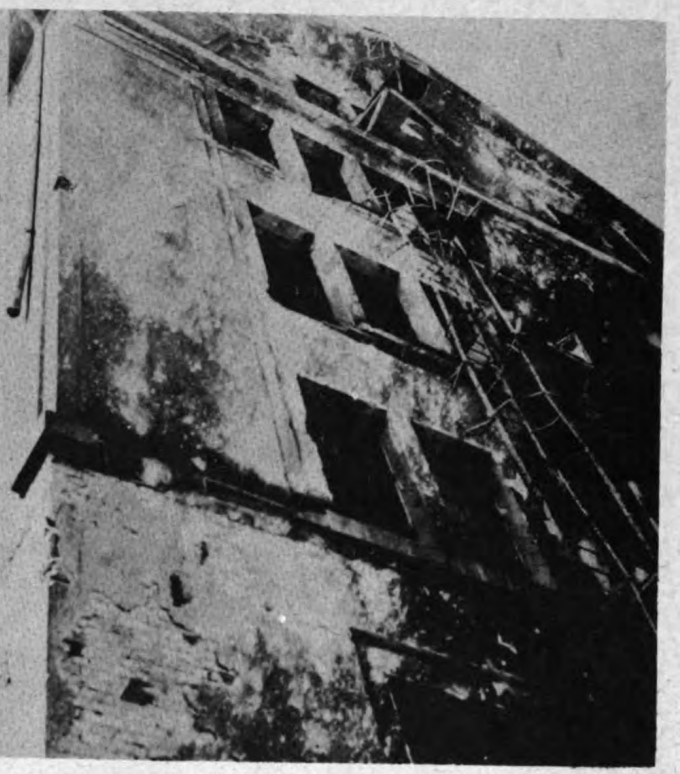


Photo 62 (right) - View showing superficial blast damage against corner of building 43.

Photo 63 (below) - View showing crater of HE at corner of building 43. Note the protective blast wall was damaged extensively while the actual corner construction of building 43 was not damaged.



T-2007

Photo 64.

Photo 65.

Photo 66.

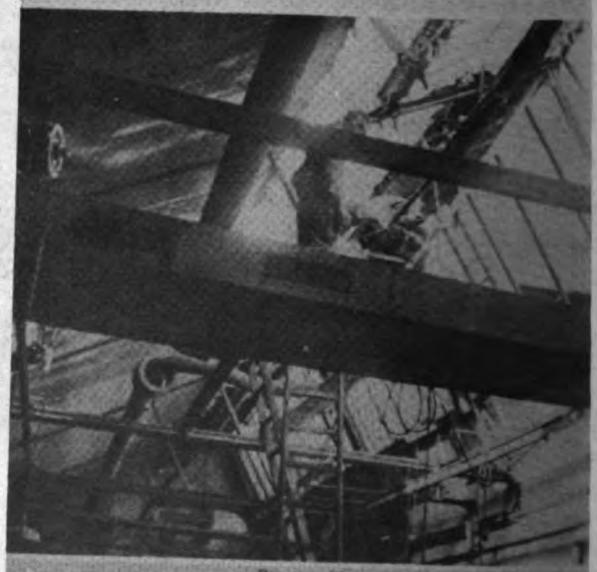


Photo 67.

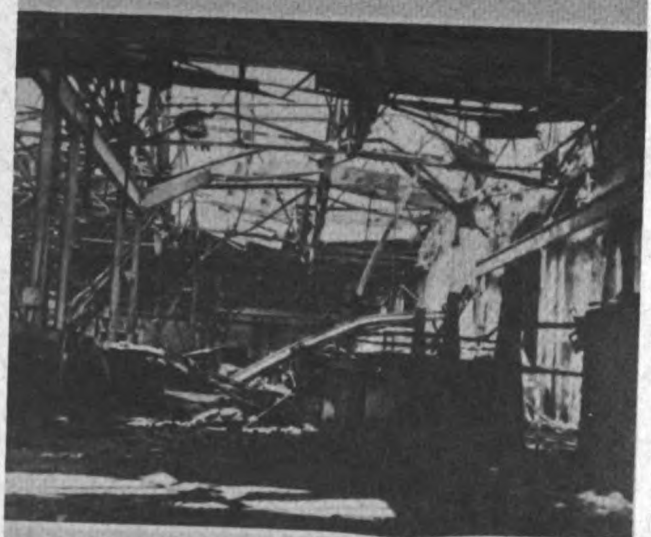


Photo 68.

Photo 69.

Photos 64 to 69 - Captured photos showing damage to machines and equipment of unidentified buildings.

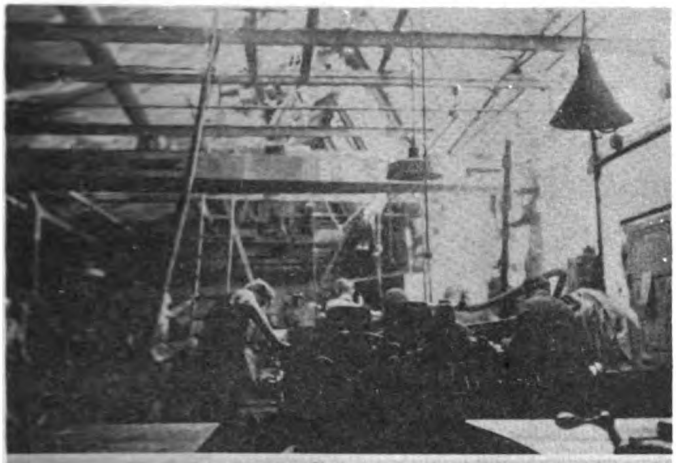


Photo 70.

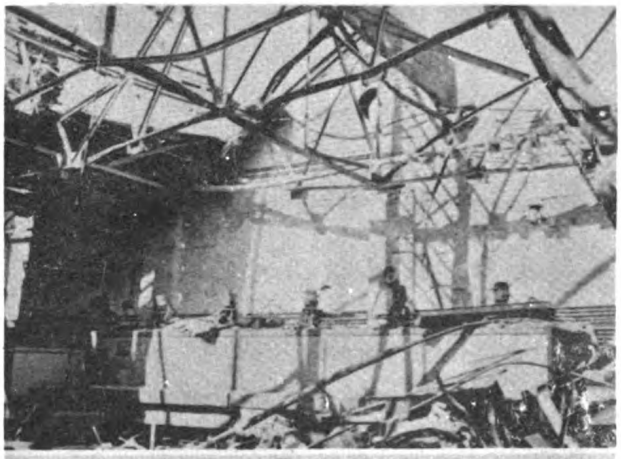


Photo 71.

Photo 72.

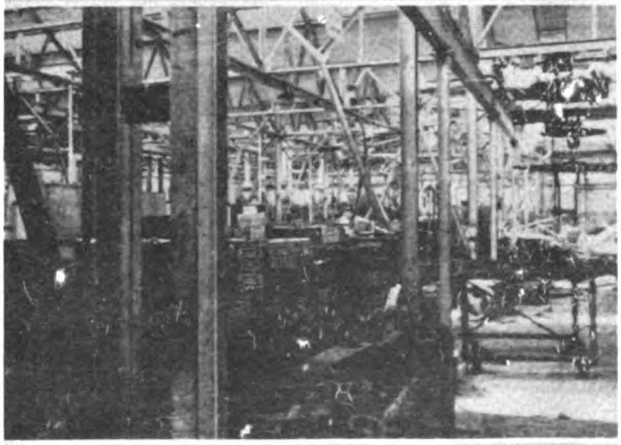


Photo 73.

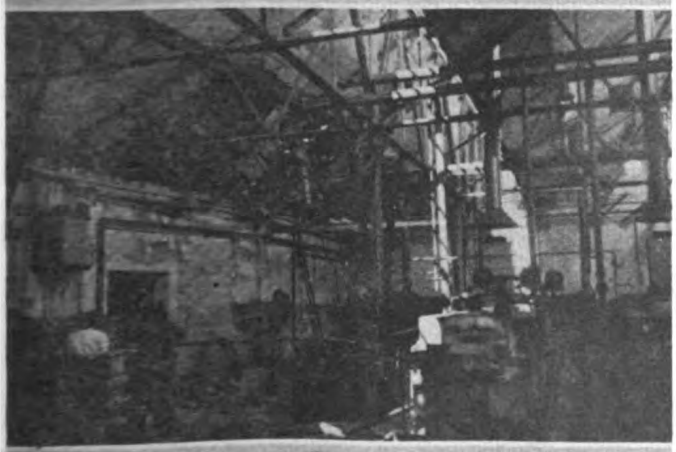


Photo 74.

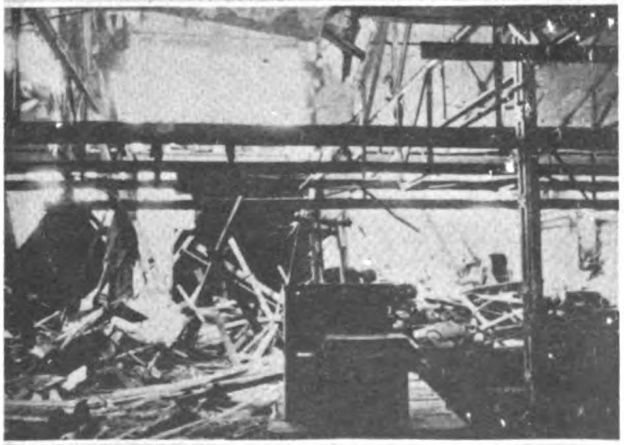


Photo 75.

Photos 70 to 75 - Captured photos showing damage to machines, equipment and stock. Note continued production activities despite damage to structures.

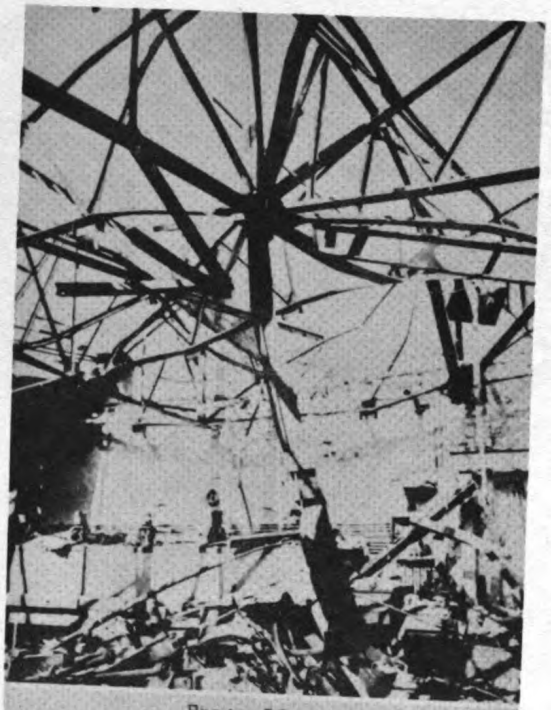


Photo 76.

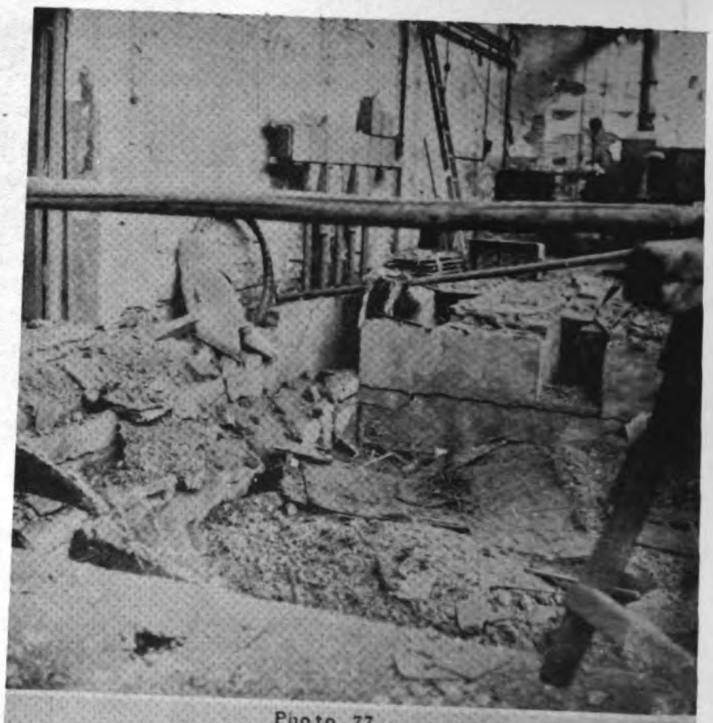


Photo 77.

Photos 76 to 78 - Captured photos showing extensive damage to structure, machines and equipment of unidentified buildings.

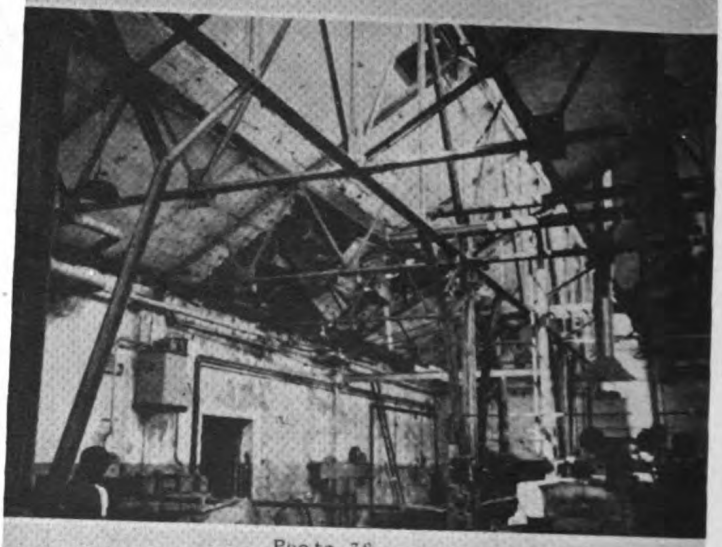
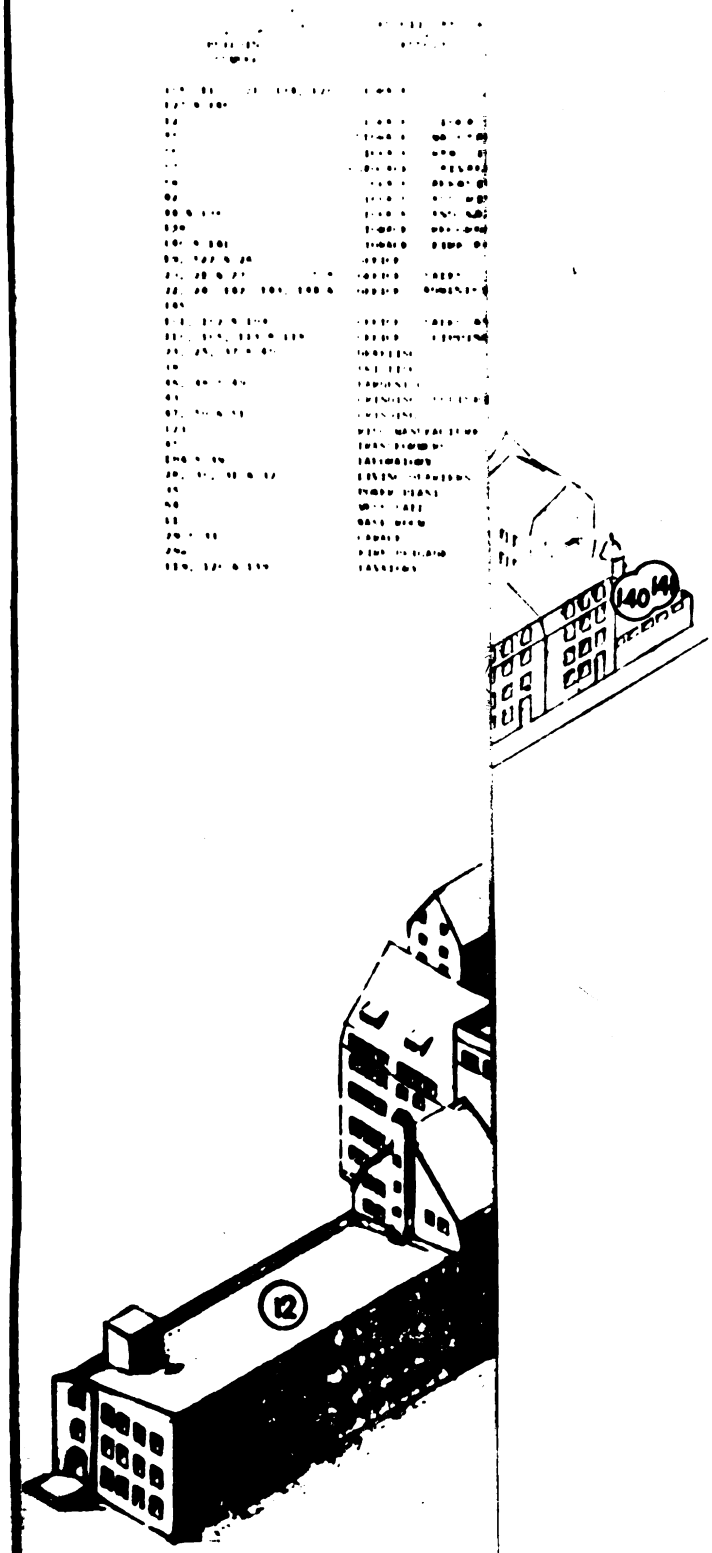


Photo 78.

Photos 79 and 80 - Captured photos showing undamaged stock piles against a background of damaged structures.



PRE-RAID

U.S. STRATEGIC BOMBING SURVEY

VKF 1

BEARINGS PLANT
SCHWEINFURT, BAVARIA

EXHIBIT A-3

736343--O -47

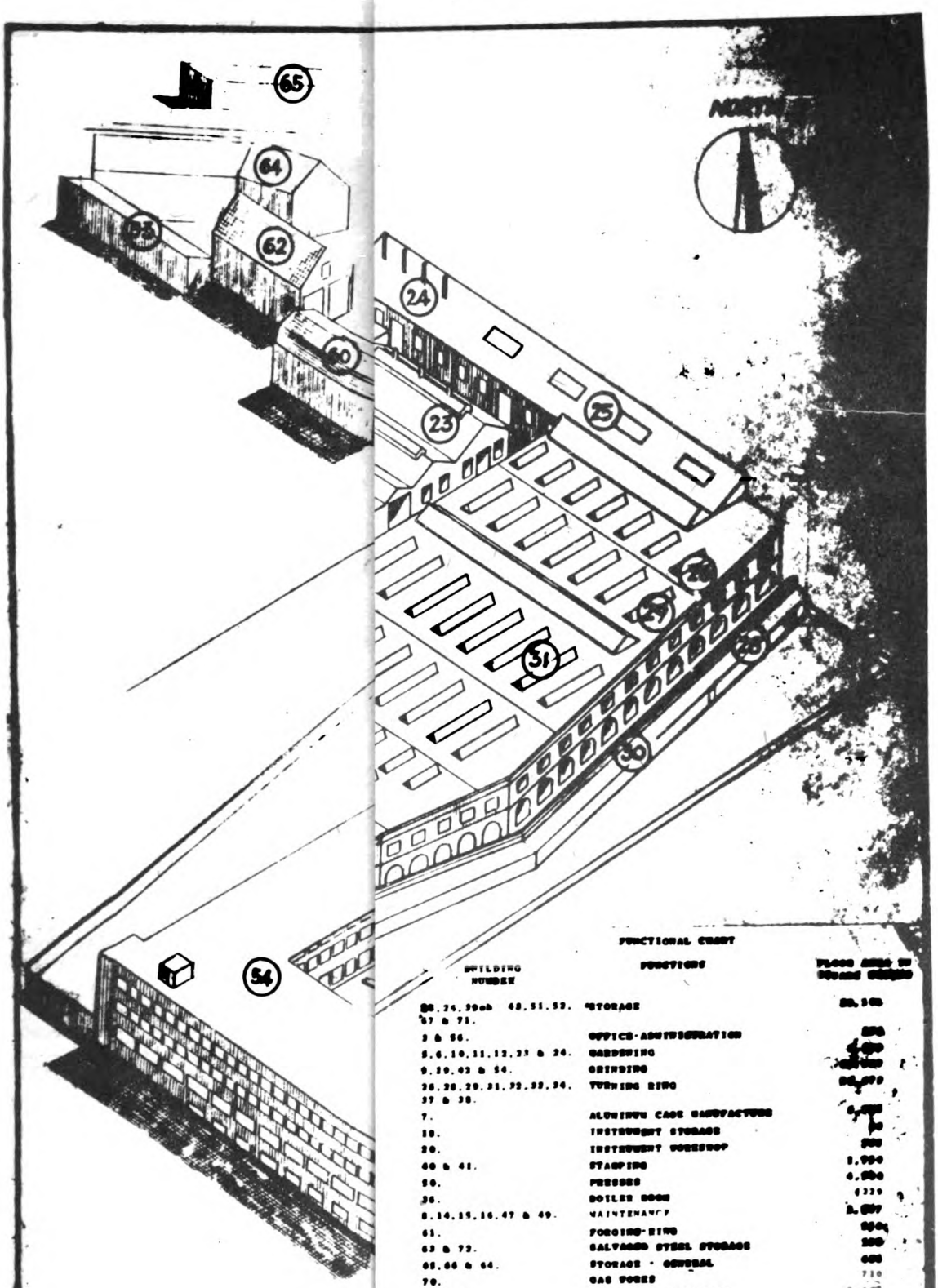
PHOTOGRAPHS 81 - 87 DELETED

A-5 PRE-RAID ISOMETRIC VIEW OF VKF II BEARINGS PLANT AT SCHWEINFURT, BAVARIA

A-6 POST-RAID ISOMETRIC VIEW OF VKF II BEARINGS PLANT AT SCHWEINFURT, BAVARIA

And

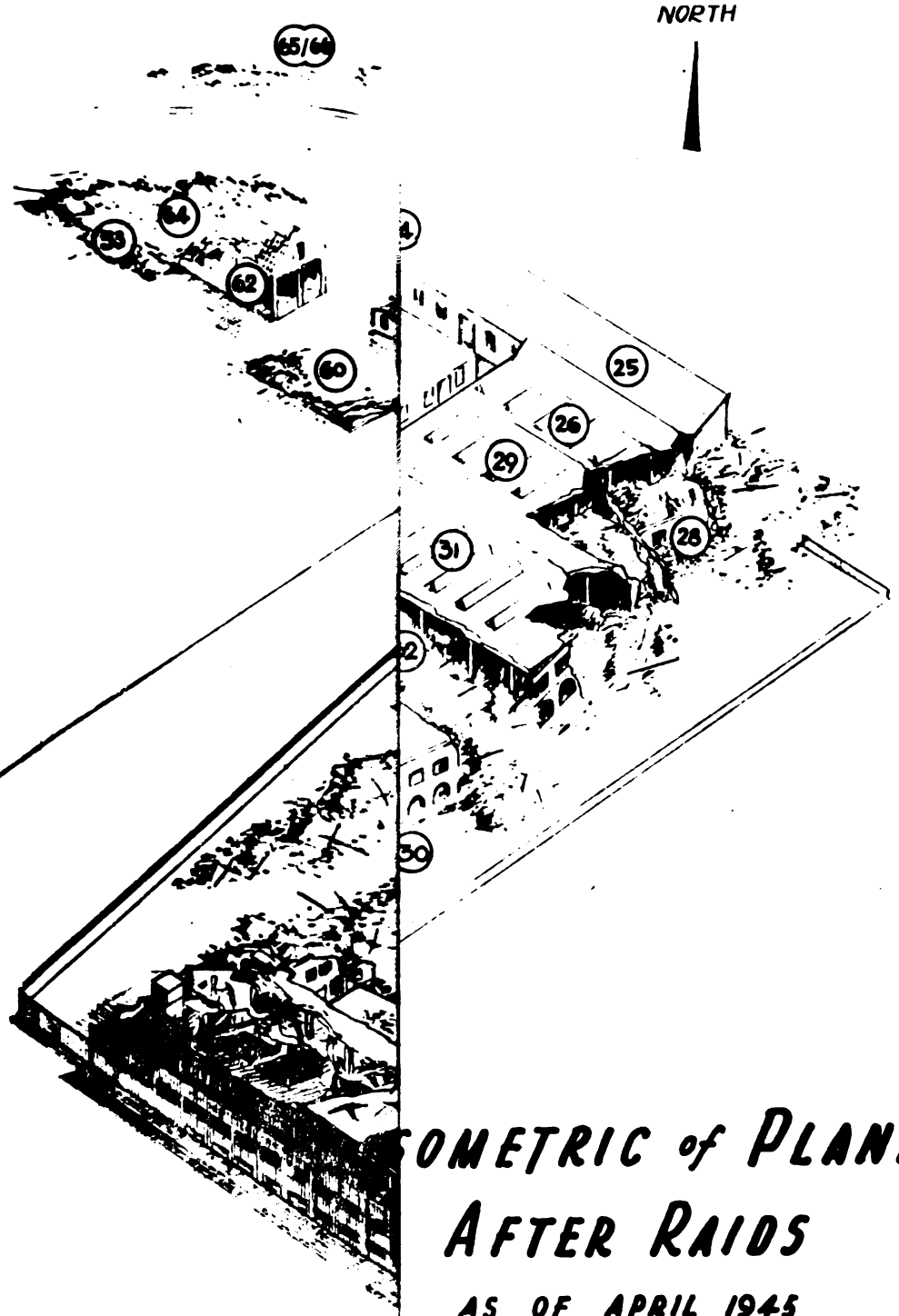
PHOTOGRAPHS 88 - 101



FUNCTIONAL CHART

BUILDING NUMBER	FUNCTIONS	FLOOR AREA IN SQUARE FEET
58, 26, 29ab 48, 51, 52, 57 & 71.	STORAGE	88,500
3 & 56.	OFFICE-ADMINISTRATION	800
5, 6, 10, 11, 12, 23 & 24.	GARDENING	4,000
9, 19, 42 & 54.	GRINDING	4,000
26, 28, 29, 31, 32, 33, 34, 37 & 38.	TURNING ROOM	24,000
7.	ALUMINUM CASE MANUFACTURE	6,000
18.	INSTRUMENT STORAGE	800
20.	INSTRUMENT WORKSHOP	800
40 & 41.	STAMPING	3,000
50.	PRESSES	4,000
36.	BOILER ROOM	1220
8, 14, 15, 16, 47 & 49.	MAINTENANCE	3,000
61.	FORGING-RING	800
63 & 72.	SALVAGED STEEL STORAGE	800
65, 66 & 64.	STORAGE - GENERAL	600
70.	GAS HOUSE	710
57 & 58.	KITCHEN & MESS HALL	1,100
1, 13, 25, 30 & 35.	MACH SHOPS	3,000
2.	FIRE DESIGNER	1000
21 & 22.	TRANSFORMERS	400
60.	LIVING QUARTERS	400

U.S. STEEL CORPORATION
NEW
BEARDS PLANT
SCHEDULE
EXHIBIT A-1



SOMETRIC of PLANT
AFTER RAIDS

AS OF APRIL 1945

POST-RAID

U.S. STRATEGIC BOMBING SURVEY
V.K.F. II
BEARINGS PLANT
SCHWEINFURT, BAVARIA
EXHIBIT A-6

736343-O-47

Photo 88 - VKF II - Ball Bearing Plant. Aerial view looking south at 400 ft. showing plant area and buildings. Plant as it appeared in May 1945 includes only the area south of road.

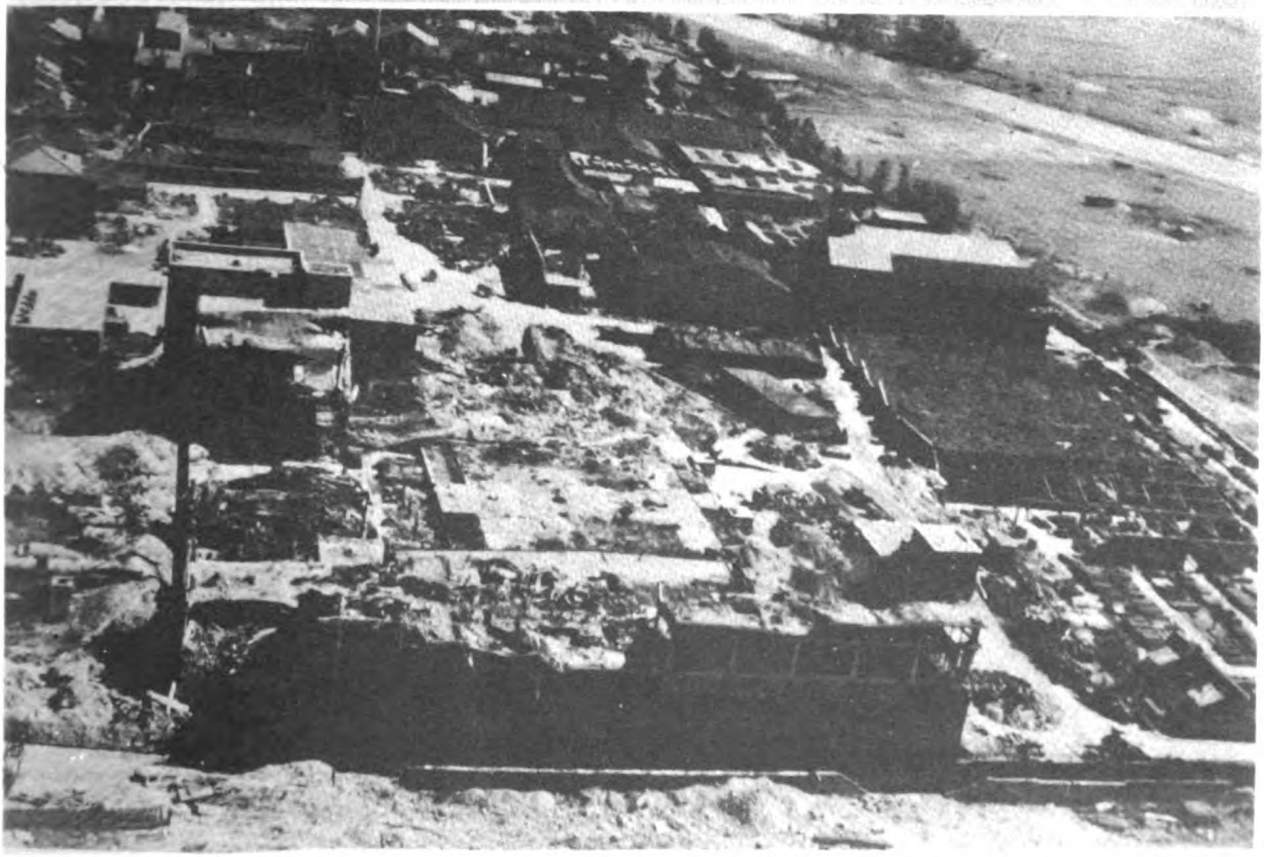


Photo 89 - Aerial view - close-up at 300 ft. looking east.

Photo 90 - Aerial view close-up at 300 ft. looking west. Note debris piled over underground structure (left center).

Photo 91 - Close-up from roof of adjoining structure, showing debris over underground concrete structure for concealment. Reinforced concrete roof slab and walls are 8 ft. thick.

Photo 92 - Blast damage to steel frame-masonry load bearing walls, bldgs. 40, 41, 42, & 43. Inclined walk (lower right) leads down to underground structure.

Photo 93 - View looking east, showing debris cleared bldg. Blast and fire destroyed wood framing of roof. Bldg. 57 in background.

Photo 94 - View Southeast towards main road showing main entrance gate (left center), tower of bldg. 54, bldgs. 47 and 48 at entrance gate, and bldg. 56, left center.

Photo 95 - View looking southeast from main road showing blast damage to reinforced concrete frame bldg. 54.

Photo 96 - View of plant yard looking northwest, showing damage to reinforced concrete structure, bldg. 1

Photo 97 - View of plant area looking southeast, showing blast damage to buildings in tower center. Note raw stock piles, lower left.

PHOTOGRAPHS 98 - 101 DELETED

PHOTOGRAPHS 102 - 111 OF BOMB DAMAGE - VKF, STUTTGART

Photo 102 - View showing heavy blast damage to steel frame-monitor type skylight, roof structure. Note damage to reinforced concrete roof deck. Reproduction of captured photo.

Photo 103 - Heavy blast damage to steel frame and heavy brick load bearing

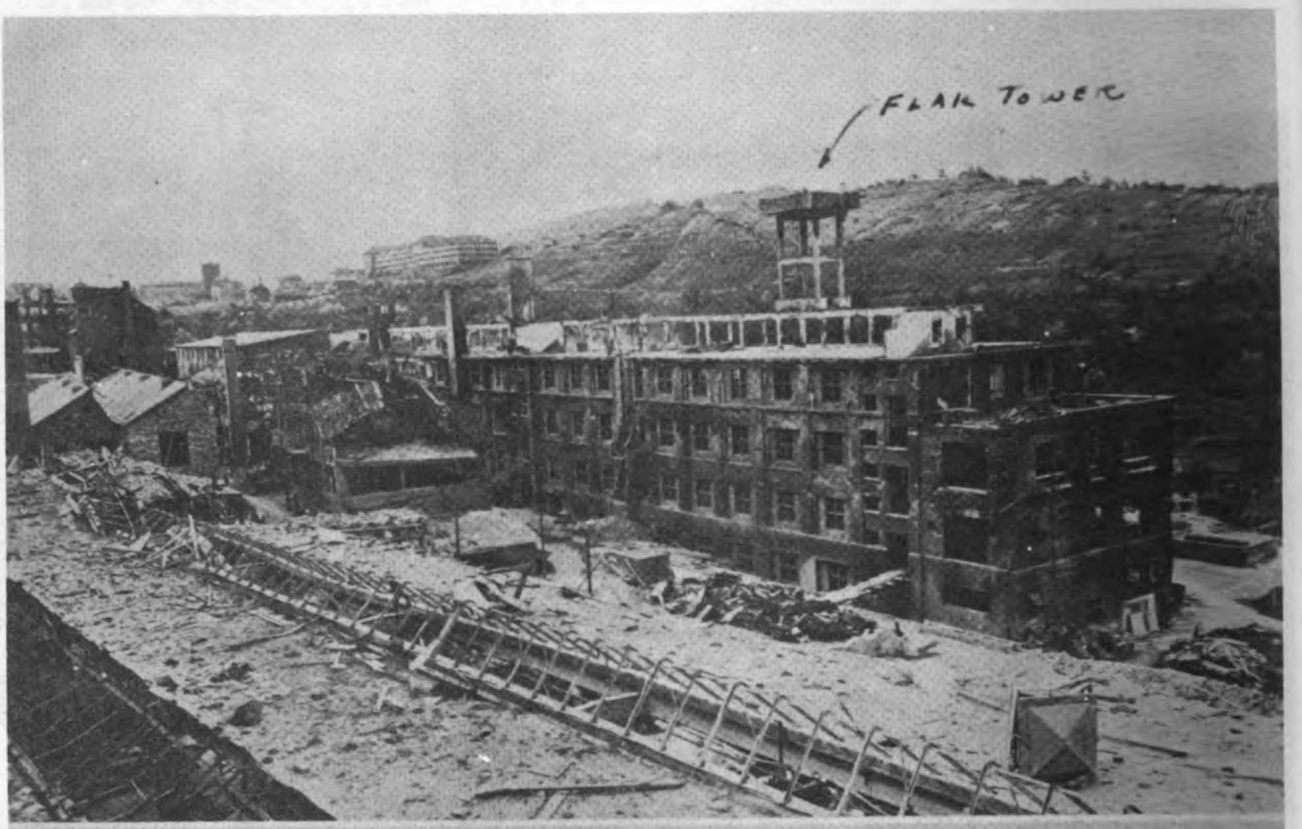


Photo 104 - View showing overall damage to plant, looking southeast. Note blast and fragmentation damage to reinforced concrete frame structure. Note reconstructed brick wall, left center, and concrete flak tower on top of exposed concrete frame. Reproduction of captured photo.

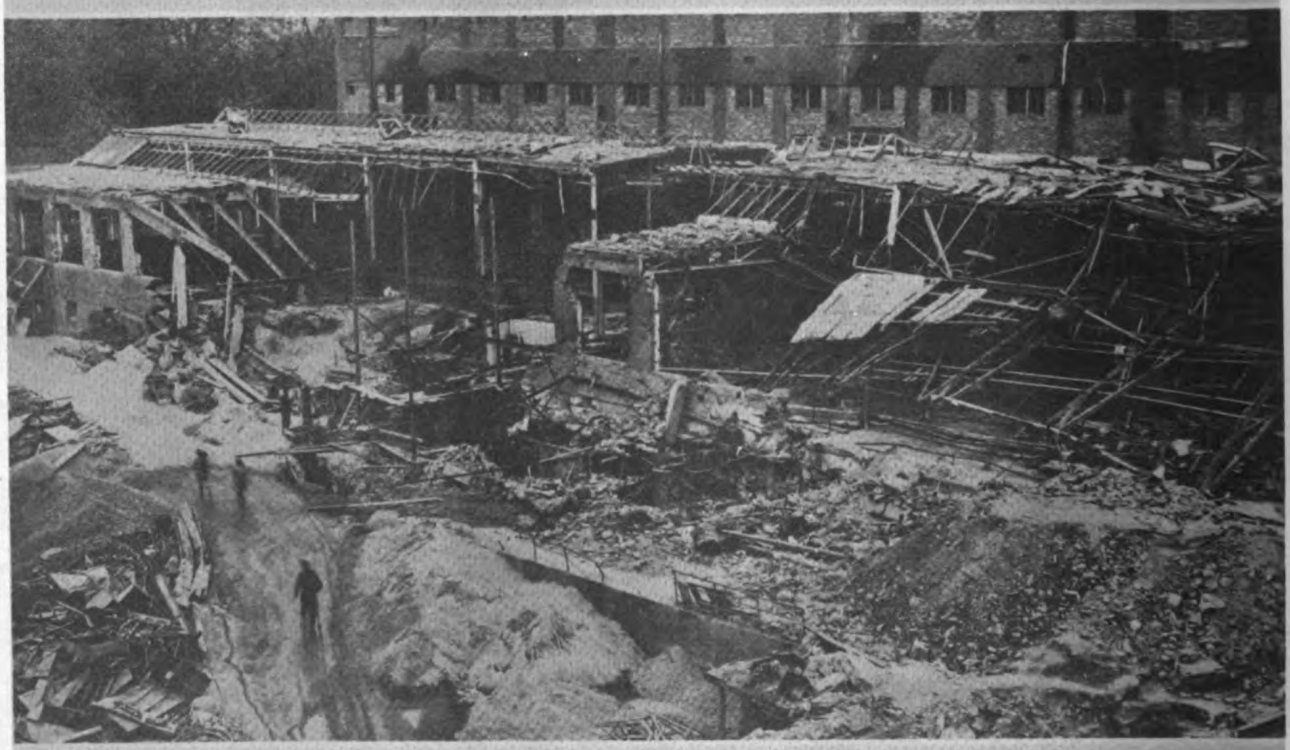


Photo 105 - View showing blast damage to steel frame structure and curtain walls reconstructed and window areas reduced in size. Reproduction of captured photo.

Photo 106 - View showing damage to roof structure of top floor of "grinding Dept". Reproduction of captured photo.

Photo 107 - Remains of masonry load bearing structure used as storage building for rings. Note finished stock. Reproduction of captured photo.

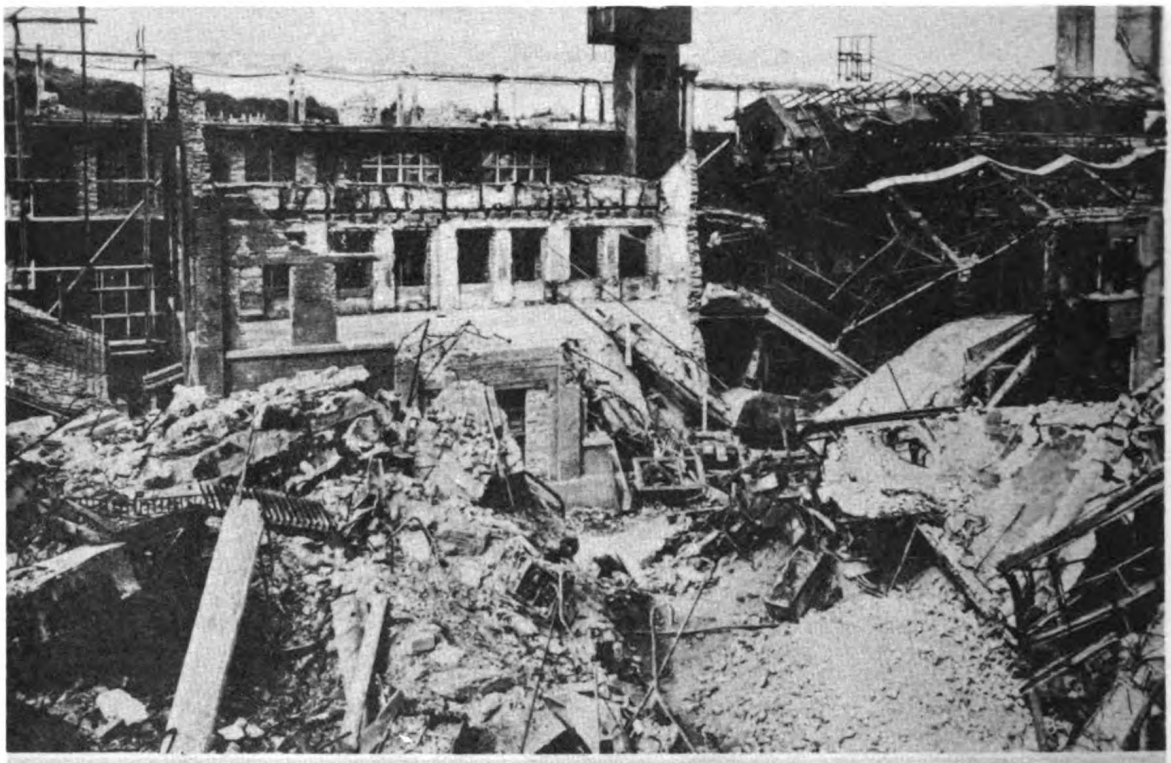


Photo 108 - View showing extensive blast and fire damage to reinforced concrete frame and steel frame structures. Note bomb crater, lower left corner and repairs to damaged curtain walls. Reproduction of captured photo.

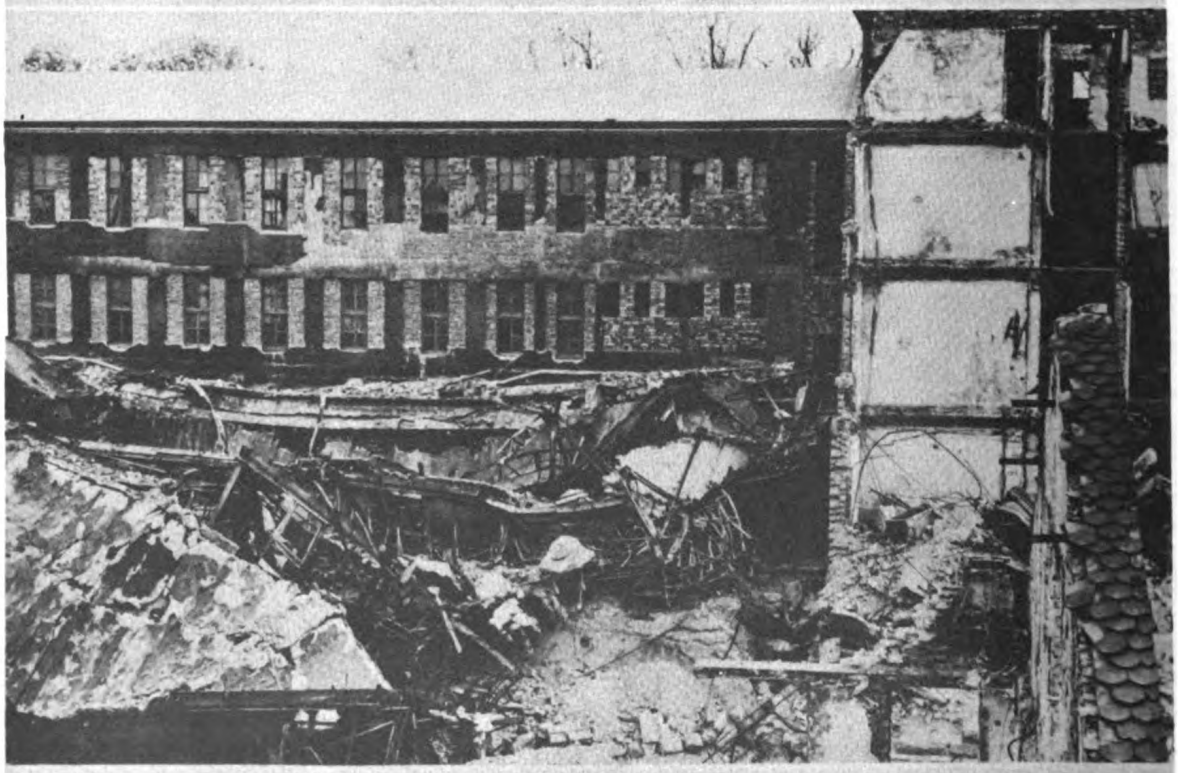


Photo 109 - Blast damage to steel frame-monitor type skylight. Note repairs to damaged walls. Reproduction of captured photo.

T-2007

Photo 110 - Blast and internal fire damage to concrete frame structure, with brick curtain walls. Note flak tower on roof and stock piles of material for rings. Note scaffolding for repairs at left end of building. Reproduction of captured photo.

T-2007

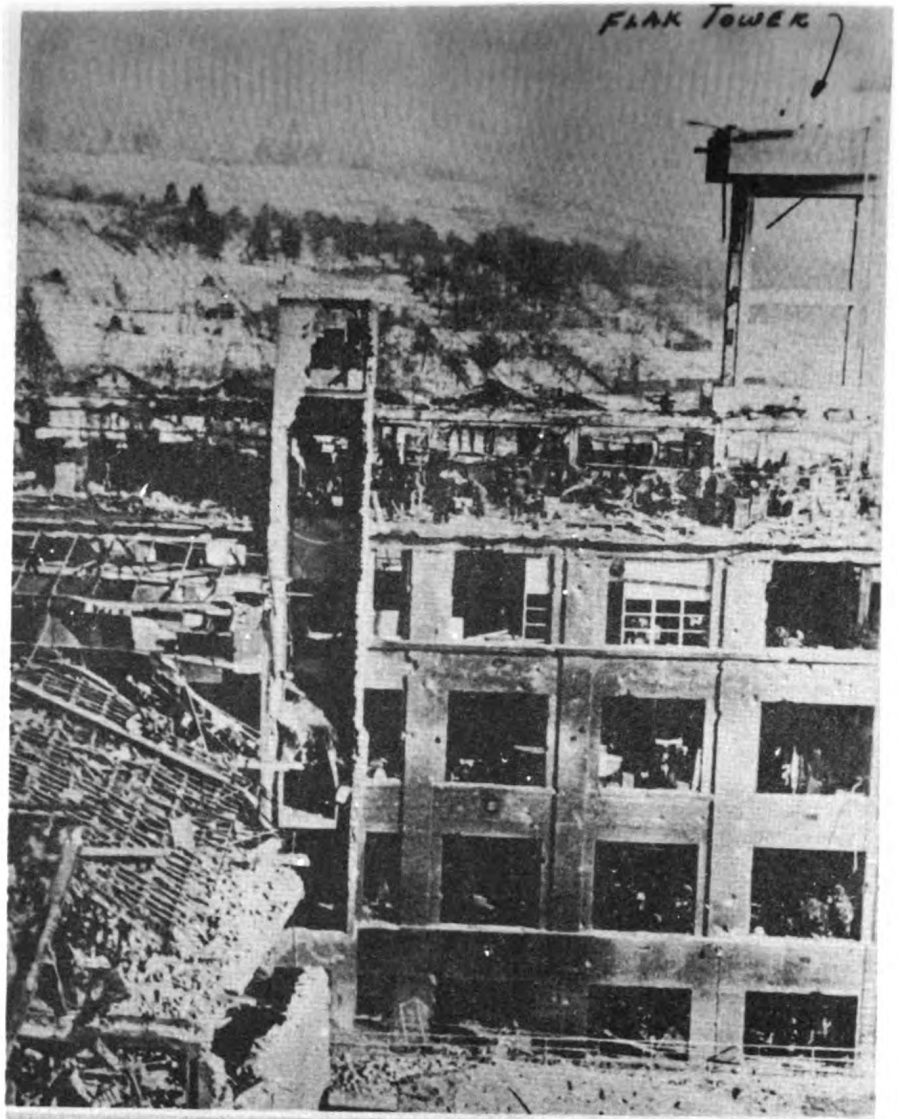


Photo 111 - Extensive blast damage to upper floor area and machines and equipment. Note damage to elevator shaft, and superficial damage to large openings due to probable blast and fragmentation. Note flak tower. Reproduction of captured photo.

B-1 - RAIDS AIMED AT BEARINGS PLANTS

B-2 - AREA RAIDS AFFECTING BEARINGS PLANTS

736343 O-47-13

OSS OF ORKERS		ENEMY COST OF RAID IN RM	FLAK AT TARGET	ENEMY A/C AT TARGET	AIRCRAFT		AIR FORCE PERSONNEL		ENEMY AIRCRAFT LOSSES	REMARKS
ed	Wounded				Lost	Damaged	Lost	Wounded		
	49	8,284,504	Moderate	Intense	36	122	364	19	148-53-18	Fighter escort grounded due to bad weather.
			Moderate	Light	5	33	51	2	12-4-2	One week's output destroyed at Bois Colombes plant.
4	107	18,234,921			62	138	599	40	186-89-27	No fighter escort for bombers on return trip.
	0	0			1	0	0	0	0	
			Intense	Light	1	49	10	2	0	Excellent fighter cover prevented large-scale German opposition.
	0	0	Light	None	0	2			0	
	0	0	Light	None	0	1			0	
	0	0	Light	None	0	1			0	
		75,000	Light	None	0	0	0	0	0	
	0	0	Light	None	0	0	0	0	0	
	0	0	Light	None	0	0	0	0	0	
	0	0	Light	None	0	0	0	0	0	
	0	0	Light	None	0	0	0	0	0	
	0									Casualties due to a direct hit on an air raid shelter.
			Moderate	Light	11	143	112	5	10-7-1	
	17	14,366,012	Light	Moderate	33	28			2-0-0	
			Light	None	0	0	0	0	0	
	25	3,700,000	Intense	Intense	37	229	395	9	42-9-14	
					3	59	40	4	0	
	0	406,602	Light	None	0	0				

EXHIBIT - B 1 (1)

OF RS ound-	ENEMY COST OF RAID IN RM	FLAK AT TARGET	ENEMY A/C AT TARGET	AIRCRAFT Lost	AIRCRAFT Dam-aged	AIR FORCE PERSONNEL Lost	AIR FORCE PERSONNEL Wound-ed	ENEMY AIRCRAFT LOSSES	REMARKS
0		Intense	Intense	20	30			116-43-16	50% of bearings in production destroyed.
0	9,740,760	Intense	Intense	14	127	139	11	22-24-13	
0	1,300,000	Moderate	Light	21	19				Intense enemy air activity enroute to target.
	11,310,680	Light	None	0	0			0-0-0	*About 85% of total floor space destroyed.
0		Intense	None	3	0	34	1	0-0-0	*3.6% machines destroy. by IB hit on storeroom.
0	0	Moderate	None	1	65	10	1	0-0-0	
0	3,186,326	Moderate	None	*3	94	38	2	0-0-0	*Two bombers lost in collision.
0		None	None	0	1	0	0	0-0-0	Smoke-screen very effective
0	0	Moderate	*Light	11	64	102	3	11-7-9	*Losses and claims are for entire Leipzig area(417 A/C)
0	9,055,416	Intense	None	1	44	9	1	0-0-0	*Included in 19 July figures.
0	8,000,000	Light	None	2	26	1	2	0-0-0	
0	4,025,089	Light	Light	0	15	0	0	0-0-0	
0	0	Light	None	0	0	0	0	0-0-0	
0	0	Light	None	0	15	0	0	0-0-0	
0	0	None	None	0	0	0	0	0-0-0	
0	0	None	None	0	0	0	0	0-0-0	
			-						No damage data available.
									No damage data available.
									No damage data available.
									No damage data available.

EXHIBIT-B1 (2)

MAP OF GERMAN ANTI-FRICTION BEARINGS INDUSTRY,

AT END OF 1944

SURVEY OF PERSONNEL, MACHINES, FLOOR SPACE OF FIRMS IN THE GERMAN ANTI-FRICTION BEARINGS INDUSTRY IN OCTOBER, 1944

EXHIBIT D

SURVEY OF PERSONNEL, MACHINES, FLOOR SPACE

GERMAN ANTI-FRICTION BEARINGS INDUSTRY

(In square meters)

October 1944

FIRMS	PERSONNEL AS OF 10 OCT 44			MACHINES			ABOVE GROUND FLOOR SPACE			PRODUCTIVE FLOOR SPACE DESTROYED & ABANDONED		
	Total	main plant	Dispersal plant	Total	Main plant	Dispersal plant	Total	main plant	Dispersal plant	Total	Main plant	Dispersal plant
	a	b	c	d	e	f	g	h	i	j	k	l
DF	1.602	1.309	293	675	515	160	23.000	18.000	5.000	2.500	2.500	-
Robert Kling	1.073	677	396	410	208	202	15.414	10.466	4.948	-	-	-
Kugelfischer	14.367	8.667	5.700	6.206	2.743	3.463	212.144	114.144	98.000	63.300	53.300	10.000
Geo. Mueller	1.628	1.266	362	685	544	141	7.000	5.000	2.000	-	-	-
V.K.f.	16.402	8.164	8.238	6.742	3.083	3.659	209.100	92.900	116.200	100.300	100.300	-
Steyr	6.017	1.172	4.845	2.300	30	2.270	27.400	5.800	21.600	55.000	55.000	-
Total	41.089	21.255	19.834	17.018	7.123	9.985	494.058	246.310	247.748	221.100	211.100	10.000

EMPLOYMENT IN THE GERMAN ANTI-FRICTION BEARINGS INDUSTRY

[illegible] Bielefeld	1.275	-	1.274	575	-	575	14.300	-	14.300	15.000	15.000	-
Fichtel u Sachs Schweinfurt	1.320	291	1.029	395	155	240	7.700	2.200	5.500	4.500	4.500	-
Koch's Adler Bielefeld	298	298	-	143	143	-	6.850	6.850	-	5.000	5.000	-
Maimach, Fabr Karlsruhe	195	195	-	54	54	-	1.850	1.850	-	205	205	-
Rondo Werk Schwarben	40	40	-	18	18	-	246	246	-	-	-	-
Wilhelm Schaeffer Katscher	227	227	-	145	145	-	3.940	3.940	-	-	-	-
Gebr Staiger St Georgur	32	32	-	21	21	-	300	300	-	-	-	-
<u>FLEXIBLE JOINTS</u>												
Wilhelm Beck Wristerlingen	107	107	-	81	81	-	910	910	-	-	-	-
Dilp Ing C Bruckner Dortmund	119	119	-	55	55	-	950	950	-	-	-	-
A Ehrenreich u Cie Dusseldorf (Mindem)	-	-	-	-	-	-	-	-	-	-	-	-
Alfred Geisel Esslingen	26	26	-	30	30	-	150	150	-	-	-	-
Giesse u Schmidt Runla	265	265	-	134	134	-	1.000	1.000	-	-	-	-
Edmund Henning Bensebausen	22	22	-	30	30	-	200	200	-	-	-	-
Kreier u Cie Pforzheim	25	25	-	21	21	-	180	180	-	-	-	-

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EXHIBIT D CONT'D

SURVEY OF PERSONNEL, MACHINES, FLOOR SPACE

GERMAN ANTI-FRICTION BEARINGS INDUSTRY

(In square meters)

OCTOBER 1944
SMALLER FIRMS

	a	b	c	d	e	f	g	h	i	j	k	l
BALL AND CROSS JOINTS												
Hans Kohler u co Wernau	80	80	-	68	68	-	960	960	-	-	-	-
Arbeitsgemeinschaft Funk, Zella Mehlis	292	242	50	198	152	47	2.077	1.727	350	-	-	-
Alfred Heyd Bissingen	146	146	-	80	80	-	1.200	1.200	-	-	-	-
Lowe-Fabriken Berlin	75	75	-	69	69	-	1.400	1.400	-	-	-	-
Karl Reich Zella Mehlis	340	340	-	300	300	-	4.000	4.000	-	-	-	-
Fritz Werner A G Berlin	1.539	1.765	774	698	329	369	7.552	3.054	4.498	350	350	-
NEEDLES												
Dreis Werk Reingruber Schwabach	20	20	-	25	25	-	100	100	-	-	-	-
Leonh Schmausser Schwabach	12	12	-	16	16	-	130	130	-	-	-	-
Trummeller u Raum Schwabach	14	14	-	20	20	-	240	240	-	-	-	-
RING BEARINGS												
Dr Hans Knappstein Berlin	28	28	-	25	25	-	180	180	-	-	-	-
Paul Raff Pfarrsheim	7	7	-	11	11	-	85	85	-	-	-	-
Wilhelm Passler Limbach	197	197	-	89	89	-	989	989	-	-	-	-
Spoerr Pfarrsheim	110	110	-	119	119	-	900	900	-	-	-	-
Anton Trenkle Triberg	176	176	-	158	158	-	750	750	-	-	-	-
REPAIR												
Albert Gerweck Schweinfurt	3	-	3	20	-	20	150	-	150	250	250	-
Mousan Frankfurt on M	70	70	-	24	24	-	650	650	-	-	-	-
Niederrh Gubstahl-walsen Fehr Dinslaken	14	14	-	10	10	-	350	350	-	-	-	-
Fritz Scholtz Arnsdall	404	404	-	208	208	-	10.750	10.750	-	-	-	-

SOURCE: Sonderring, Walslager

EXHIBIT E

	May	June	July	Aug	Sept	Oct	Nov	Dec
632*	15,475	15,651	16,010*	15,948	16,839	17,137	16,961	17,352
031*	8,938	9,254	9,483*	9,225	9,772	9,941	9,826	10,153
131*	6,747	6,851	6,850*	6,672	6,680*	6,686	6,392	6,496
900*	2,191	2,403	2,633*	2,553	3,092*	3,255	3,434	3,657
221	4,241	4,111	4,212	4,371	4,541	4,587	4,501	4,560
379	3,170	3,046	3,143*	3,110	3,160*	3,198	2,487	2,491
342*	1,071	1,065	1,069	1,261	1,381*	1,389	2,014	2,069
900*	1,798	1,756	1,780*	1,813	1,987	2,067	2,095	2,099
480*	498*	530	535*	539	539	542	539	540
416*	14,026	14,299	14,507*	15,087	15,044	15,004	15,087	15,321
504*	11,276	11,615	11,800*	12,346	12,194	12,305	12,290	12,666
561	6,671	6,409	5,900	5,961	5,690	5,673	5,605	5,587
043	4,605	5,206	5,900*	6,385	6,504	6,632	6,685	7,079
172	2,112	2,082	2,100*	2,140	2,265	2,121	2,226	2,083
640	638	602	607	601	585	578	571	572
000*	4,960	5,200*	5,400*	5,702	5,932	6,040	6,153	6,153
						1,160		
						4,880		
425*	1,473	1,500*	1,525*	1,549	1,589	1,609	1,552	1,522
150*	1,173	1,250*	1,250*	1,249	1,262	1,271	1,204	1,172
275*	300*	250*	275*	300*	327	338	348	350
475*	1,509	1,530*	1,550*	1,573	1,602	1,628	1,671	1,693
771	775	794	789	891	1,072	1,091	1,124	1,093
750*	774	850*	950*	1,050*	1,150*	1,975	1,400*	1,900*
310	324	400	450	520	530	532	550	450
440	450	450	500	530	620	843	850	850
000	4,500	4,800	5,000	5,200	5,400	5,481	5,300	5,100
469	43,492	44,624	45,324	47,000	48,628	49,365	49,248	49,534

MONTHLY PRODUCTION OF ANTI-FRICTION BEARINGS, BY PIECES FOR EACH MAJOR TYPE, 1943 - 44

1944							
May	June	July	Aug	Sept	Oct	Nov	Dec
4,650	5,825	6,039	6,372	7,393	7,570	7,248	6,828
329	497	563	658	614	601	569	509
101	129	152	194	273	216	208	231
13	27	24	41	37	30	29	35
208	233	299	277	280	337	423	258
5	6	3	5	5	4	8	5
5,306	6,717	7,080	7,547	8,601	8,758	8,485	7,866
1,085	1,219**	1,154	1,107	899	715	543	489
739	849	954	1,082	1,127	1,089	1,088	993
308	370	288	219	272	259	320	305
17,500	22,000	20,000	21,817	21,700	23,800	24,015	20,000
4,162	3,721	4,137	7,508	7,713	7,947	8,132	9,208
667	1,056	919	1,233	1,301	1,340	1,256	1,188
46,000	46,000	46,000	46,000	60,000	56,360	69,259	53,000

** Note that the needs for needle bearings constantly declined after this date, falling to 450,000 at end of year.

Source: Sonderring Walzlager.

MONTHLY PRODUCTION OF ANTI-FRICTION BEARINGS, BY PIECES FOR EACH SIZE RANGE, 1943 - 44

SIZE GROUP DISTRIBUTION OF PRODUCTION, 1943-1944

(Numbers in thousands)

Outer diameter in mm	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1943												
Gr I - up to 21.9 (extra small)	2,496	2,456	2,977	2,475	2,885	2,770	2,908	2,677	2,962	2,853	2,928	2,837
Gr II - 22-61.9 (small)	3,077	3,083	3,617	3,346	3,698	3,266	3,418	3,255	3,437	3,100	3,709	3,446
Gr III - 62-119.9 (medium A)	1,278	1,332	1,549	1,398	1,610	1,374	1,539	1,250	1,293	929	972	958
Gr IV - 120-239.9 (medium B)	238	321	325	296	328	383	382	308	312	249	305	358
Gr V - 240-599.9 (large)	8	8	9	8	8	12	12	10	9	7	10	15
Gr VI-VIII - over 600 (large)	1	1	1	1	1	1	1	1	1	1	1	2
No definite size	91	84	99	99	238	90	119	99	116	77	157	-
Total	7,189	7,285	8,577	7,623	8,568	7,896	8,379	7,600	8,130	7,216	8,082	7,616
1944												
Gr I - up to 21.9 (extra small)	2,580	2,156	2,440	2,130	2,514	3,216	3,093	3,076	3,892	4,058	3,858	3,678
Gr II - 22-61.9 (small)	2,909	2,330	1,729	1,188	1,947	2,482	2,800	2,996	3,138	3,348	3,241	2,886
Gr III - 62-119.9 (medium A)	1,032	905	770	418	471	653	811	1,012	1,066	929	989	919
Gr IV - 120-239.9 (medium B)	325	257	220	159	221	350	363	450	453	421	391	371
Gr V - 240-599.9 (large)	19	13	6	13	14	15	12	12	14	18	15	11
Gr VI-VIII - over 600 (large)	1	1	1	1	1	2	1	1	1	1	1	1
Total	6,866	5,662	5,166	3,909	5,168	6,718	7,080	7,547	8,564	8,775	8,495	7,866

Source: Sonderring Walzlager.

QUARTERLY PRODUCTION AND DELIVERIES, TOTALS AND INDICES

EXHIBIT H

BEARINGS - PRODUCTION AND DELIVERIES

Source: Sonderring Walzlager and Fachgruppe Walzlager und Triebwerke

QUARTERLY PRODUCTION - THOUSAND PIECES

	I/43	II/43	III/43	IV/43	I/44	II/44	III/44	IV/44
VKF	12,380	12,688	12,645	11,585	5,945	6,010	9,188	10,258
FAG	6,141	6,298	6,034	5,940	5,156	3,279	5,135	5,738
Steyr	1,886	2,271	2,527	2,586	2,302	434	2,054	1,994
Muller	1,067	1,156	1,080	965	1,315	1,830	1,872	1,845
DKF	290	286	304	332	306	273	230	281
Kling	199	213	220	250	179	188	228	219
Small firms	1,083	1,176	1,299	1,270	2,492	3,778	4,484	4,801
TOTAL	23,046	24,088	24,109	22,928	17,695	15,792	23,191	25,136

QUARTERLY DELIV (UMSATZ) THOUSAND RM

	I/43	II/43	III/43	IV/43	I/44	II/44	III/44	IV/44
VKF	29,154	28,673	27,171	21,534	18,078	20,294	22,993	23,315
FAG	22,654	23,787	20,062	11,318	23,730	18,656	19,844	26,161
Steyr	6,193	8,203	8,715	6,691	8,195	6,537	9,378	8,854
Muller	931	1,088	1,010	779	1,385	1,623	1,915	1,820
DKF	3,480	4,187	3,963	4,013	3,807	3,773	4,029	3,811
Kling	753	837	837	837	961	1,222	1,309	1,083
Small firms	2,883	3,583	3,526	4,178	5,084	5,900	7,077	6,312
TOTAL	66,048	70,358	65,284	49,350	61,240	58,005	66,545	71,356

INDEX QUARTERLY PRODUCTION II/43=100

	I/43	II/43	III/43	IV/43	I/44	II/44	III/44	IV/44
VKF	98	100	100	91	47	47	72	81
FAG	98	100	96	94	82	52	82	91
Steyr	83	100	111	114	101	19	90	88
Muller	92	100	94	83	114	158	162	160
DKF	101	100	106	116	107	95	80	98
Kling	93	100	104	117	84	88	107	103
Small firms	92	100	110	108	212	321	381	408
TOTAL PRODUCTION	96	100	100	95	73	66	96	104

INDEX QUARTERLY DELIVERIES II/43=100

	I/43	II/43	III/43	IV/43	I/44	II/44	III/44	IV/44
VKF	102	100	95	75	63	71	80	81
FAG	95	100	84	48	100	78	83	110
Steyr	75	100	106	82	100	80	114	108
Muller	86	100	93	72	127	149	176	167
DKF	83	100	95	96	91	90	96	91
Kling	90	100	100	100	115	146	156	129
Small firms	80	100	98	117	142	165	198	176
TOTAL DELIVERIES	94	100	93	70	87	82	95	101

MACHINE TOOLS AT VKF, SCHWEINFURT

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THE GERMAN ANTI-FRICTION BEARINGS INDUSTRY EXHIBIT I

TOTAL MACHINES IN SCHWEINFURT

REFERENCE NO.	DESCRIPTION (LOCATION AND FUNCTION OF MACHINERY)	TOTAL ON 16.8.43	TOTAL ON 15.10.43 NEW MACHINES ADDED FROM 16.8.43 - 15.10.43	MACHINES DISPERSED	TOTAL BEFORE THE ATTACK OF 14.10.43	MACHINES DESTROYED ON 14.10.43	MACHINES DAMAGED ON 14.10.43	TOTAL AFTER THE ATTACK OF 14.10.43
1	Ring Production	1,620	17	34	1,603	13	29	1,561
2	Non Ferrous solid Cage Production	108	3	-	111	-	1	110
3	Pressed Cage Production	170	-	19	151	-	17	134
4	Ball-Production	673	-	23	650	73	65	512
5	Tabered Roller Production	58	-	-	58	-	1	57
6	Spherical Roller Production	67	-	-	67	-	8	59
7	Assembly	163	-	-	163	3	1	159
8	Machine Shop and Tool Room	214	1	-	215	3	33	179
9	Housing Manufacture	20	-	-	20	20	-	-
	TOTAL MACHINES	3,093	21	76	3,038	112	155	2,771

(Source: VKF Inventory Control 22.6.45)

THE GERMAN ANTI-FRICTION BEARINGS INDUSTRY EXHIBIT I

TOTAL MACHINES IN SCHWEINFURT

REFERENCE NO	DESCRIPTION (LOCATION AND FUNCTION OF MACHINERY)	TOTAL ON 26.2.44 NEW MACHINES ADDED FROM 15.10.43 - 26.2.44	MACHINES DAMAGED ON 14.10.43	MACHINES DISPERSED	TOTAL BEFORE THE ATTACK ON 24/25.2.44	MACHINES DESTROYED ON 24/25.2.44	MACHINES DAMAGED ON 24/25.2.44	TOTAL AFTER THE ATTACK
1	Ring Production	12	29	214	1,388	104	27	1,257
2	Non Ferroussolid Cage Production	-	1	73	38	-	-	38
3	Pressed Cage Production	-	17	18	133	4	2	127
4	Ball-Production	12	65	216	373	39	-	334
5	Tabered Roller Production	-	1	-	58	-	-	58
6	Spherical Roller Production	-	8	-	67	13	-	54
7	Assembly	-	1	28	132	15	-	117
8	Machine Shop and Tool Room	16	33	-	228	-	8	220
9	Housing Manufacture	-	-	-	-	-	-	-
	TOTAL MACHINES	40	155	549	2,417	175	37	2,205

(Source: VKF Inventory control 22.6.45)

THE GERMAN ANTI-FRICTION BEARINGS INDUSTRY EXHIBIT I

TOTAL MACHINES IN SCHWEINFURT

REFERENCE NO.	DESCRIPTION (LOCATION AND FUNCTION OF MACHINERY)	TOTAL ON 22.7.44 NEW MACHINES ADDED FROM 26.2.44-22.7.44	MACHINES DAMAGED ON 24/25.2.44	MACHINES DISPERSED	TOTAL BEFORE THE ATTACK ON 19/24.7.44	MACHINES DESTROYED ON 19/24.7.44	MACHINES DAMAGED ON 19/24.7.44	TOTAL AFTER THE ATTACK ON 19/24.7.44
1	Ring Production	2	27	186	1,100	4	23	1,073
2	Non Ferroussolid Cage Production	-	-	5	33	-	1	32
3	Pressed Cage Production	-	2	125	4	-	4	-
4	Ball-Production	7	-	34	307	10	34	263
5	Tabered Roller Production	-	-	58	-	-	-	-
6	Spherical Roller Production	-	-	54	-	-	-	-
7	Assembly	-	-	3	114	-	17	97
8	Machine Shop and Tool Room	-	8	-	228	-	17	211
9	Housing Manufacture	-	-	-	-	-	-	-
	TOTAL MACHINES	9	37	465	1,786	14	96	1,676

(Source: VKF Inventory Control 22.6.45)

THE GERMAN ANTI-FRICTION BEARINGS INDUSTRY EXHIBIT I

TOTAL MACHINES IN SCHWEINFURT

REFERENCE NO.	DESCRIPTION (LOCATION AND FUNCTION OF MACHINERY)	TOTAL ON 9.10.44 NEW MACHINES ADDED FROM 22.7.44 - 9.10.44	MACHINES DAMAGED ON 19/24.7.44	DISPERSED MACHINES	TOTAL BEFORE THE ATTACK ON 9.10.44	MACHINES DESTROYED ON 9.10.44	MACHINES DAMAGED ON 9.10.44	TOTAL AFTER THE ATTACK ON 9.10.44
1	Ring Production	1	23	141	956	4	10	942
2	Non Ferroussolid Cage Production	-	1	4	29	-	-	29
3	Pressed Cage Production	-	4	-	4	-	4	-
4	Ball-Production	2	34	110	189	9	21	159
5	Tabered Roller Production	-	-	-	-	-	-	-
6	Spherical Roller Production	-	-	-	-	-	-	-
7	Assembly	-	17	4	110	-	-	110
8	Machine Shop and Tool Room	1	17	-	229	31	41	157
9	Housing Manufacture	-	-	-	-	-	-	-
	TOTAL MACHINES	4	96	259	1.517	44	76	1.397

(Source: VKF Inventory Control 22.6.45

THE GERMAN ANTI-FRICTION BEARINGS INDUSTRY EXHIBIT I

TOTAL MACHINES IN SCHWEINFURT

REFERENCE NO.	DESCRIPTION (LOCATION AND FUNCTION OF MACHINERY)	TOTAL ON 31.3.45 NEW MACHINES ADDED FROM 9.10.44 - 31.3.45	MACHINES DAMAGED ON 9.10.44	MACHINES DISPERSED	TOTAL ON 31.3.45
1	Ring Production	5	10	76	881
2	Non Ferroussolid Cage Production	-	-	2	27
3	Pressed Cage Production	-	4	4	-
4	Ball-Production	-	21	44	136
5	Tabered Roller Production	-	-	-	-
6	Spherical Roller Production	-	-	-	-
7	Assembly	-	-	4	106
8	Machine Shop and Tool Room	2	41	165	35
9	Housing Manufacture	-	-	-	-
	TOTAL MACHINES	7	76	295	1.185

(Source: VKF Inventory Control 22.6.45

THE GREAT ANTI-FRICTION BEARINGS INDUSTRY — **EXHIBIT J**

MACHINES DESTROYED BY AIR ATTACKS

REFERENCE NO	DESCRIPTION	17 Aug 1943	14 Oct 1943	24 Feb 1944	13 Apr 1944	27 Apr 1944	19 Jul 1944	21 July 1944	9 Oct 1944	Total
1	Ring Production	-	13	104	-	-	3	1	4	125
2	Nonterrous solid cage prod.	-	-	-	-	-	-	-	-	-
3	Pressed cage production	-	-	4	-	-	-	-	-	4
4	Ball production	-	73	39	-	-	-	10	9	131
5	Tapered roller production	-	-	-	-	-	-	-	-	-
6	Spherical roller production	-	-	13	-	-	-	-	-	13
7	Assembly	-	3	15	-	-	-	-	-	18
8	Machine shop and tool room	-	3	-	-	-	-	-	31	34
9	Housing manufacture	-	20	-	-	-	-	-	-	20
		-	112	175	-	-	3	11	44	345
	Machines in store-room on 24 Feb 1944 completely destroyed									161
									Total	506

THE GREAT ANTI-FRICTION BEARINGS INDUSTRY

MACHINES DAMAGED BY AIR ATTACKS

REFERENCE NO	DESCRIPTION	17 Aug 1943	14 Oct 1943	24 Feb 1944	13 Apr 1944	27 Apr 1944	19 Jul 1944	21 Jul 1944	9 Oct 1944	Total
1	Ring production	15	14	27	1	2	1	19	10	89
2	Nonterrous solid cage prod	-	1	-	-	-	-	1	-	2
3	Pressed cage production	2	15	2	-	-	-	4	4	27
4	Ball production	-	65	-	-	-	3	31	21	120
5	Tapered roller production	-	1	-	-	-	-	-	-	1
6	Spherical roller production	-	8	-	-	-	-	-	-	8
7	assembly	-	1	-	-	15	2	-	-	18
8	Machine shop and tool room	4	29	8	10	-	-	7	41	99
9	Housing manufacture	-	-	-	-	-	-	-	-	-
	Total	21	134	37	11	17	6	62	76	364

Source: VKF INVENTORY RECORDS
22 June 1945

MACHINE TOOLS DESTROYED OR DAMAGED AT VKF, SCHWEINFURT

DISPERSAL FACTORIES OF FAG, SCHWEINFURT

Refe-rence No	Loca-tion	Funct Mach
2	Elfers-hausen	Non soli prod
1		(Ring (duct
2	Lieb-authal	(Non (soli (prod
3		(Pres (cage (duct
7		(Asse
4	Bay-reuth	Ball duct
1		(Ring (duct
4	Main-leus	(Ball (duct
7		(Asse
1	Fuchs-stadt	(Ring (duct
8		(Mach (shop (tool
3		(Pres (cage (duct
5	Schauen-stein	(Tape (roll (duct
6		(Sphe (roll (duct
	Total Dispersed Schweinfurt	
1	Erkner	Ring ducti
1	Neu-stadt	(Ring (ducti
4		(Ball (ducti
1	SKF	(Ring (ducti
7	Purst-ein	(Asse (
	Total Dispers Machines	
	Total Machines Total Machines New Machines in 16 Aug 1943 to	

DISPERSAL FACTORIES OF FAG, SCHWEINFURT

Photo 112 - Steyr underground dispersal plant, Linz, Austria.

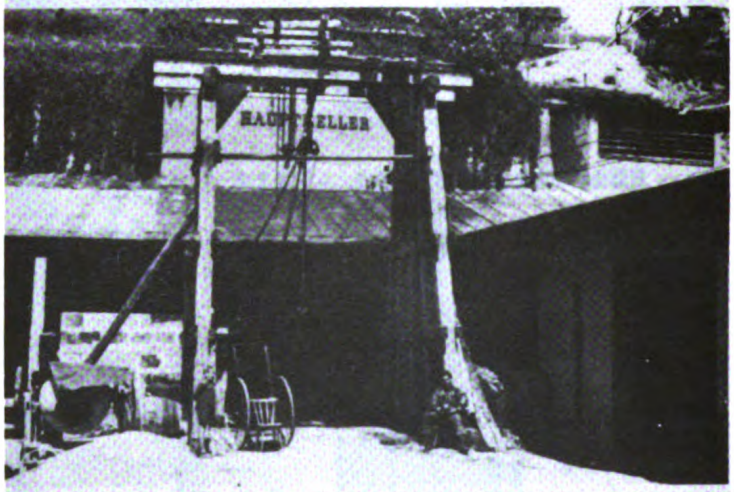
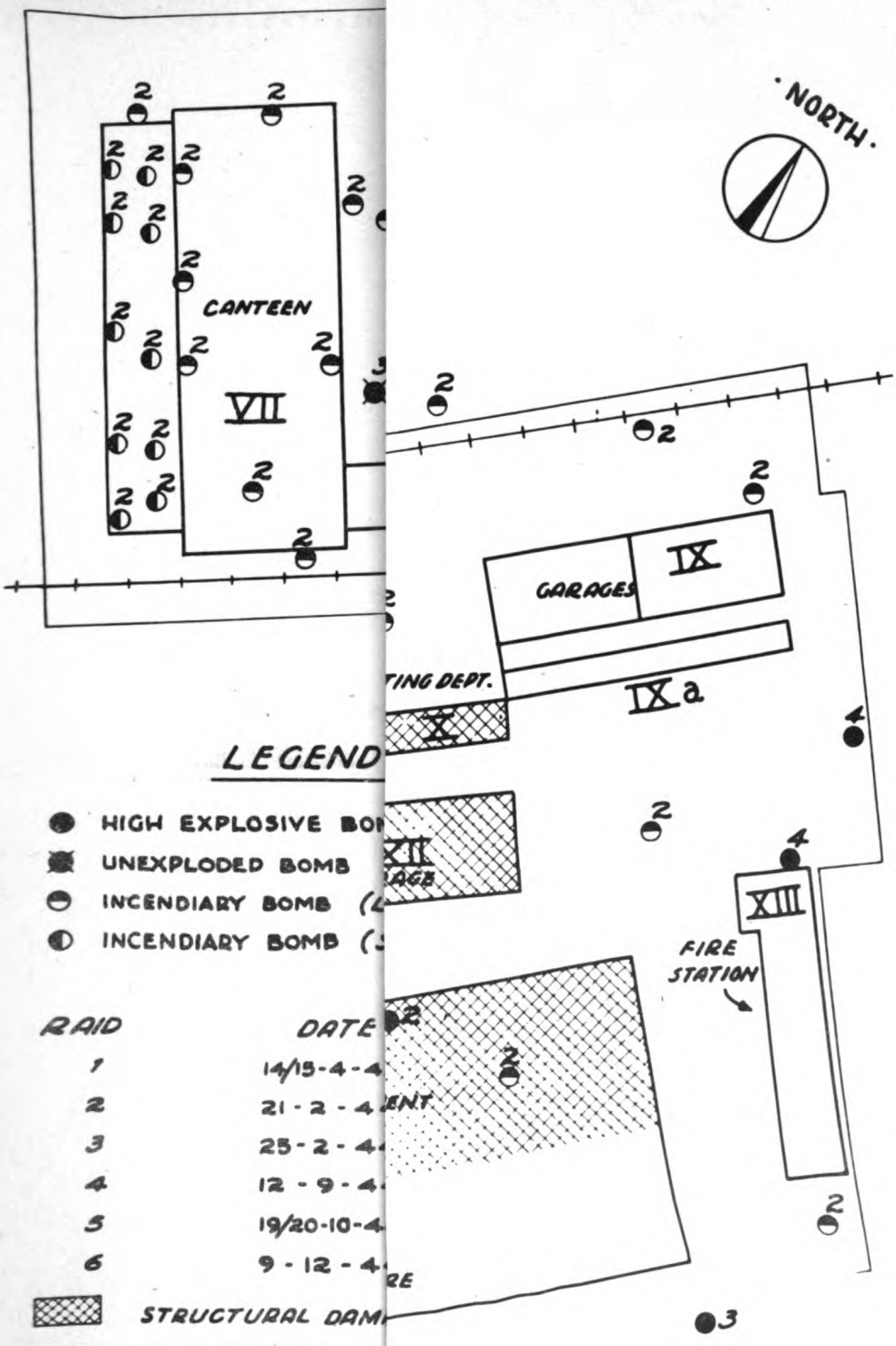


Photo 113 - Entrances to underground factories at Linz. Note thickness of earth.

Photo 114 - Brewery above underground factory at Linz.

LAYOUT PLAN FOR STEYR-DAIMLER-PUCH-BEARINGS PLANT



U.S. STRATEGIC BOMBING SURV
GERMAN ANTI-FRICTION BEARINGS REPORT.
EXHIBIT "O"

VARIOUS DECREES AND ORGANIZATION PLANS OF SONDERRING WALZLAGER

THE GERMAN ANTI-FRICTION BEARINGS INDUSTRY

EXHIBIT P

The Chief of the Sonderring "Anti-friction Bearings" in the Hauptring Produktionsmittel and Maschinenelemente of the Reichsminister fur Bewaffnung und Munition. — 1 July 1942 — Dr Be/se

Organization of the Sonderring Walzlager

Chief of the Sonderring: George Schafer — Kugelfischer (FAG)

Deputy: Wilhelm Jurgensmeyer (VKF).

\+ + + + + + + + +

Sonderring-- Planning for demand, distribution of orders, control of stocks, planning for machines, construction.	The Chief	
Army, Navy, and Civilian Requirements	Dr Becker Lang	(FAG) (FAG)
Specialist for Tanks	Reifenrath	(VKF)
Specialist for Railway Equipment	Vogel	(FAG)
Specialist for Aircraft	Merkle Brockert	(FAG) (VKF)
Working Ring for Standardization and new designs	Jurgensmeyer	(VKF)
Working Ring for Simplification and Substitution of Types	Bues	(FAG)
Working Ring for Material Problems	Diergarten	(FAG)
Working Ring for Small Bearings	Schweickardt	(VKF)
Working Ring for Large Bearings	Menne	(FAG)
Working Ring for Rollers	Schweickardt	(VKF)
Working Ring for Needle Bearings	Witte	(VKF)
Working Ring for Half-track Needles	Offermanns	(Schumag)

EXHIBIT F(CONT'D)

Working Ring for Half-track Bushings	Niediek	(Durkoppwerke)
Working Ring for Labor Supply	Tully	(VKF)
Working Ring for Management of Materials	Kilian	(FAG)
Working Ring for Costs	Rossner	(Steyr)
Berlin Liaison Office with Ministries & Wehrmacht	Dreschmann	(FAG)
Working Ring for Gelenk-Lager	Schoen	(Berko-Werke)
Working Ring for Kugel- and Kreuz-Gelenke	Wommelsdorf	(Werner AG)

Office of the Sonderring:

Business Manager	Dr Erno Becker	(FAG)
Deputy	Max Bergmann	(FAG)

EXHIBIT P (CONT'D)

D U P L I C A T E

The Reichsminister for
Armament & War Production:
Chief of Armament Delivery Office

Schweinfurt, 15.10.43

SECRET
No 4150

TO:
All main committees.
The SRW

SUBJECT: Supply of Bearings.

During the attack of Oct 14, there were destroyed a large part of the documents on production planning and of the order cards of the bearings firms on the subsequent deliveries of finished goods will take place centrally through the SRW, Working Ring on Regulation of Demands (Arbeitsring Bedarfslenkung.) To this end the following measures are necessary:

1). For the bearings industry a general blocking of all deliveries is decreed, to take effect immediately. Delivery can only follow permission from the SRW. Excepted herefrom are small business, the satisfaction of pressing repair needs, and deliveries between bearings firms.

2). Consumers will no longer give their demands directly to the bearings producers. Orders henceforth are to be sent in to the Arbeitsring Bedarfslenkung SRW through the Working and Special Committees, who will thereby be responsible for seeing that only the most pressing needs are submitted. Quantities that exceed the preliminary quota or contain replacement demands incapable of satisfaction must be correspondingly reduced by the committees. The equipment for which the bearings are needed, and the priority rating thereof, are in all cases to be stated. The committees must advise their firms to announce immediately their needs for the balance of the year, broken down by months, and at the same time forbid them all further direct correspondence with the bearings firms or the SRW.

3). The SRW, Arbeitsring Bedarfslenkung will make provisions for the necessary allotments within the framework of available possibilities, in accord with the decree of the RLA.

This preliminary decree will shortly be amplified by more specific rules of the SRW. It is intended to apply to the whole economy.

The current address of the Arbeitsring Bedarfslenkung is as follows:

Dr Enno Becker
c/o Kugelfischer-Georg Schafer & Co
Schweinfurt/Main
Steinstrasse, City Trade School.

Heil Hitler!
/s/ Walter Schieber

EXHIBIT P (CONT'D)

S O N D E R R I N G W A L Z L A G E R Secret No 4148g
Working Ring on Regulation of Demand

Directive on the Bearing Supply Situation.

1) All orders with the bearings industry are to be considered as cancelled. The steel quota question will be regulated in a separate ordinance.

2) Consumers will announce their needs to the appropriate Ausschusse by means of the attached form. Stocks will be reckoned with. The request is in all cases to be limited to the bare minimum, by decree of the Rustungslieferungs Amt. The same applies to replacement additions.

3) The equipment committees will check the announced needs against a rigid standard and transmit them in the form of a consolidated delivery plan to the Arbeitsring Bedarfslenkung in SRW. The processing will be taken in hand by the existing control agencies in accordance with the attached plan of organization. Hence it is not necessary to submit a breakdown by consignee.

4) The Arbeitsring Bedarfslenkung will give the equipment committee an allotment, naming the supplier and the available quantity, as well as an order number. The agreed amount needed will be certified out of stocks or new production by the Working group on Production Planning.

5) The equipment committee will distribute the available quantity among the equipment-making firms and stipulate that they place corresponding orders with the designated bearing manufacturers with reference to the order number. The Arbeitsring Bedarfslenkung should receive a copy of this plan of distribution.

6) The committee must notify their member firms to report cancellations of orders, as a consequence of changes in construction or program, immediately to the bearings firms who have to fill the orders. The latter will in turn inform the Arbeitsring Bedarfslenkung.

SRW
WR RD

/s/ Dr Becker

Schweinfurt 16.10.1943

EXHIBIT P (CONT'D)

SONDERRING WALZLAGER
Working Ring Regulation of Demand SECRET 4149g

Directive for Bearings Plants

1) All stocks on hand are to be inventoried and brought together in a list by type. In the list the present place of storage is to be stated. This decree refers to the combined stocks both in plants and in shipping depots.

2) The bearings factories will certify which types are in production, and will state in what quantity and at what time these can be expected. Production no longer possible through enemy attack is to be left out of consideration in this statement.

3) The cessation of manufacture of new types and quantities goes into immediate effect, except on express permission from the "Working Group on Production Planning" through the Arbeitsring Bedarfslenkung.

4) The orders on hand are to be considered cancelled. Future deliveries will take place only on permission of the Arbeitsring Bedarfslenkung. As soon as pressing orders from customers come up, the bearings producers may request approval for delivery of them. In so doing, the priority rating and the eventual use (when possible the equipment program) are in every case to be stated. Small orders in branch offices, and imperative repair orders of small extent are not included in this forbidding of delivery.

5) The steel certificates already received from the customer will later be charged up. Since quota documents have been destroyed by fire in the case of the Schweinfurt firms, a special regulation is necessary and is being jointly prepared with the Wirtschaftsgruppe Maschinenbau; on this more detailed notification will follow.

6) The placing of new orders will be done in accordance with the attached directive for the equipment-manufacturing industry. As soon as cancellations through changes in programs or construction are made known to the Arbeitsring Bedarfslenkung of this freed capacity.

Sonderring Walzlager
Working Ring on Regulation of
Demand

/s/ Dr Becker

Schweinfurt 16.10.43

EXHIBIT P (CONT'D)

SRW
WR RD

Instructions for the staff of the
Working Ring on Regulation of Demand (Arbeitsring Bedarfslenkung)

The tasks of the Arbeitsring Bedarfslenkung are:

1) Central regulation of orders.
2) Central planning of production, including managing and distribution of stocks.

A. Tasks of the "Working Group on Regulation of Orders"

The control offices are responsible for:

1) Consolidation of demands in accordance with Equipment or Production Programs.
2) Processing of the statements of needs from the Committees.

Demand consists of current need (new construction) and replacement.

3) Certification and allocation of deliveries in conjunction with the Planning Offices of the SRW.
4) Preliminary examination of delivery slips.

B. Tasks of "Production Planning"

The Planning Offices are responsible for:

1) Certification of the stated demand within the compass of available possibilities from stocks and production.
2) Assigning production quotas to manufacturers.
3) Allocation of deliveries within the frame of the directives given out by the Arbeitsring Bedarfslenkung.
4) Granting of delivery slips on motion of the office for regulation of orders.
5) Proposal of expansions to the "Working Staff on Rationalizing" (Arbeits Stab Rationalisierung.)

/s/ Dr Becker

19.10.43

EXHIBIT P (CONT'D)

WR RD

CONFIDENTIAL
Only for official use.

Plan of Organization
of
"Working Ring on Regulation of Demand"(Arbeitsring Bedarfslenkung)

III. Working Ring on Regulation of Demand

Leader: Dr Erno Becker (FAG)
Deputy: Brockert (VKF)

1.) "Regulation of Orders" Leader: Lang

1.1	Working group on Bearings & components	Fleischer
1.11	Office of Control for Motor Vehicles	Fleischer
1.111	Tanks	
1.112	Tractors	
1.113	Bicycles	
1.12	Office of Control for Air	Scheible
1.121	Motors	
1.122	Airframes	
1.123	Airplane armament	
1.13	Office of Control for Electrical appliances, communications equipment, etc.	Kinter
1.131	Electrical goods	
1.132	Communications equipment	
1.133	General equipment, torpedoes	
1.14	Office of Control for Weapons, shipbuilding, rail transport	Koch
1.141	Weapons	
1.142	Shipbuilding	
1.143	Railway equipment	
1.15	Order inspection office for special needs	Herrman (?)
1.151	Machines	
1.152	Generators	
1.153	Cutting & welding equipment	
1.154	Drilling equipment	
1.155	Mining	
1.156	Export	

1.2	Working group on Gelenklager	H. Schoen, Berke-
1.3	Halftrack needle bearings	Dir Niedick, Durkopp-Bielefeld
1.4	Halftrack needles	Dir Offermanns, Schumag/Aachen
1.5	Kugel- & Kreuz gelenke	Erdmann, Werner/Berlin

EXHIBIT P (CONT'D)

2.)	"Production Planning" Leader:	Brockert.
2.1	Working group bearings & Components	Brockert
2.11	Planning office for current production	Nubel
2.111	Bearings	
2.112	Rolling parts	
2.113	Retainers	
2.114	Others	
2.12	Planning office for Stocks	Weich
2.2	Working Group Gelenklager	Schoen
2.21	Planning office for current production	
2.22	Planning office for Stocks	
2.3	Working Group Halftrack Needle Bearings	Niedlek
2.31	Planning Office for Current Production	
2.32	Planning Office for Stocks	
2.4	Working Group Halftrack Needles	Offermanns
2.41	Planning Office for current Production	
2.42	Planning Office for stocks	
2.5	Working Group Kugel- and Kreuzgelenke	Wommelsdorf
2.51	Planning Office for Current Production	
2.52	Planning Office for Stocks	

(Addresses)

Dr Becker

Schweinfurt, 18 October 43

EXHIBIT P (CONT'D)

The Reichsminister for Armament
and War Production.
RLA WF

D E C R E E

Concerning the Mobilization of Bearing Reserves

26 October 1943

On the basis of the paragraph of the first enabling ordinance to the edict of the Fuhrer and Reich Chancellor on the appointment of a Reichminister for Armament and Munitions of 20.3.40 (RGBL. 1940 roem. 1,s.514), the ordinance concerning movement of goods (?) in the draft of 1.12.42 (RGBL.1942 roem 1, s.686) and the Fuhrers decree on Concentration of War Industry of 2.9.43 (RGBL.1942, roem.1 s.529) is ordered:

roem. 1

All dealers and users of bearings must in accordance with more detailed instructions of the SRW Arbeitsring Bedarfslenkung report their stocks of bearings and components as of 1 November 1943 to the local compenent Gau chamber of commerce (industrial department).

The obligation to report can in case of changes in stocks be fixed for a later date.

roem. 2

The SRW Arbeitsring Bedarfslenkung will draft the reported bearings reserves for covering military needs in addition to current production. To this end can the Ring order the sale of a part or the whole sum of the stock of an armament factory. The sale must follow the original price.

In case of necessity of compulsion, the seized stocks are to be confiscated by the competent Rustungs-inspection on authority of the Reichs' laws.

roem. 3

Incorrect reports will be punished in accordance with the decree on the protection of the Armament industry of 21.3.42 (RGBL. 1942 roem. 1, S. 165)

For The Reichsminister for Armament
and War Production:

/s/ Walther Schieber

EXHIBIT P (CONT'D)

SRW
WR RD

Rules of the Arbeitsring Bedarfslenkung in SRW on determining the Stocks of Bearings and components in accordance the Decree about Mobilization of bearings reserves of 26.10.43

1. All users of bearings including dealers must combine their Stocks of bearings and components (balls, rollers, needles) in a list per the above official notice and submit the report in duplicate by the 15 November 1943 as of the report date 1 Nov 43 to the local competent Gau Chamber of Commerce (Industrial department).

The stock reports are in the future to be repeated quarterly. The report dates are:

February 1
May 1
August 1
November 1

The reports are to be submitted at the latest on the third day of the stated month.

2. Obligatory in the report is the whole stock. With each bearing type or component is to be stated the average monthly use, derived from the previous half-year.

3. The industrial department of the Gau Chamber of Commerce will process the announcement. To this end, specialists have been nominated by the Arbeitsring Bedarfslenkung in the SRW. These specialists will proceed for the duration of the commission to the ind. dept.

4. The received stock reports will be examined on the basis of the directives from the WR RD and the free stocks will be certified for the armaments industry. The certification will be informally made and confirmed in writing. To dispose of certified bearings stocks or to remove them is forbidden, unless a dispersal appears necessary on account of raid danger. In that case is the new location to be reported by the next mail.

SRW
Arbeitsring Bedarfslenkung

Schweinfurt
2 Nov 1943

Dr Becker

(Attached is a form --- "W A L Z L A G E R B E S T A N D") containing the things asked for above. Very simple form)

UNITED STATES STRATEGIC BOMBING SURVEY

LIST OF REPORTS

The following is a bibliography of reports resulting from the Survey's studies of the European and Pacific wars. Those reports marked with an asterisk (*) may be purchased from the Superintendent of Documents at the Government Printing Office, Washington, D. C.

European War

OFFICE OF THE CHAIRMAN

*1 The United States Strategic Bombing Survey: Summary Report (European War)
*2 The United States Strategic Bombing Survey: Overall Report (European War)
*3 The Effects of Strategic Bombing on the German War Economy

AIRCRAFT DIVISION

(By Division and Branch)

*4 Aircraft Division Industry Report
5 Inspection Visits to Various Targets (Special Report)

Airframes Branch

6 Junkers Aircraft and Aero Engine Works, Dessau, Germany
7 Erla Maschinenwerke G m b H, Heiterblick, German
8 A T G Maschinenbau, G m b H, Leipzig (Mockau), Germany
9 Gothaer Waggonfabrik, A G, Gotha, Germany
10 Focke Wulf Aircraft Plant, Bremen, Germany
11 Messerschmitt A G, Augsburg, Germany — Over-all Report; Part A; Part B; Appendices I, II, III
12 Dornier Works, Friedrichshafen & Munich, Germany
13 Gerhard Fieseler Werke G m b H, Kassel, Germany
14 Wiener Neustaedter Flugzeugwerke, Wiener Neustadt, Austria

Aero Engines Branch

15 Bussing NAG Flugmotorenwerke G m b H, Brunswick, Germany
16 Mittel-Deutsche Motorenwerke G m b H, Taucha, Germany
17 Bavarian Motor Works Inc, Eisenach & Durrerhof, Germany
18 Bayerische Motorenwerke A G (BMW) Munich, Germany
19 Henschel Flugmotorenwerke, Kassel, Germany

Light Metal Branch

20 Light Metals Industry of Germany — Part I, Aluminum; Part II, Magnesium
21 Vereinigte Deutsche Metallwerke, Hildesheim, Germany
22 Metallgussgesellschaft G m b H, Leipzig, Germany
23 Aluminiumwerk G m b H, Plant No. 2, Bitterfeld, Germany
24 Gebrueder Giulini G m b H, Ludwigshafen, Germany
25 Luftschiffbau, Zeppelin G m b H, Friedrichshafen on Bodensee, Germany
26 Wieland Werke A G, Ulm, Germany
27 Rudolph Rautenbach Leichmetallgiessereien, Solingen, Germany
28 Lippewerke Vereinigte Aluminiumwerke A G, Lunen, Germany
29 Vereinigte Deutsche Metallwerke, Heddernheim, Germany
30 Duerener Metallwerke A G, Duren Wittenau-Berlin & Waren, Germany

AREA STUDIES DIVISION

*31 Area Studies Division Report
32 A Detailed Study of the Effects of Area Bombing on Hamburg
33 A Detailed Study of the Effects of Area Bombing on Wuppertal
34 A Detailed Study of the Effects of Area Bombing on Dusseldorf
35 A Detailed Study of the Effects of Area Bombing on Solingen
36 A Detailed Study of the Effects of Area Bombing on Remscheid
37 A Detailed Study of the Effects of Area Bombing on Darmstadt
38 A Detailed Study of the Effects of Area Bombing on Lubeck
39 A Brief Study of the Effects of Area Bombing on Berlin, Augsburg, Bochum, Leipzig, Hagen, Dortmund, Oberhausen, Schweinfurt, and Bremen

CIVILIAN DEFENSE DIVISION

*40 Civilian Defense Division—Final Report
41 Cologne Field Report
42 Bonn Field Report
43 Hanover Field Report
44 Hamburg Field Report—Vol I, Text; Vol II, Exhibits
45 Bad Oldesloe Field Report
46 Augsburg Field Report
47 Reception Areas in Bavaria, Germany

EQUIPMENT DIVISION

Electrical Branch

*48 German Electrical Equipment Industry Report
49 Brown Boveri et Cie, Mannheim Kafertal, Germany

Optical and Precision Instrument Branch

*50 Optical and Precision Instrument Industry Report

732203—47

Abrasives Branch

*51 The German Abrasive Industry
52 Mayer and Schmidt, Offenbach on Main, Germany

Anti-Friction Branch

*53 The German Anti-Friction Bearings Industry

Machine Tools Branch

*54 Machine Tools & Machinery as Capital Equipment
*55 Machine Tool Industry in Germany
56 Herman Kolb Co., Cologne, Germany
57 Collet and Engelhard, Offenbach, Germany
58 Naxos Union, Frankfort on Main, Germany

MILITARY ANALYSIS DIVISION

59 The Defeat of the German Air Force
60 V-Weapons (Crossbow) Campaign
61 Air Force Rate of Operation
62 Weather Factors in Combat Bombardment Operations in the European Theatre
63 Bombing Accuracy, USAAF Heavy and Medium Bombers in the ETO
64 Description of RAF Bombing
64a The Impact of the Allied Air Effort on German Logistics

MORALE DIVISION

*64b The Effects of Strategic Bombing on German Morale (Vol I and Vol II)

Medical Branch

*65 The Effect of Bombing on Health and Medical Care in Germany

MUNITIONS DIVISION

Heavy Industry Branch

*66 The Coking Industry Report on Germany
67 Coking Plant Report No. 1, Sections A, B, C, & D
68 Gutehoffnungshuette, Oberhausen, Germany
69 Friedrich-Alfred Huette, Rheinhausen, Germany
70 Neunkirchen Eisenwerke A G, Neunkirchen, Germany
71 Reichswerke Hermann Goering A G, Hallendorf Germany
72 August Thyssen Huette A G, Hamborn, Germany
73 Friedrich Krupp A G, Borbeck Plant, Essen, Germany
74 Dortmund Hoerder Huettenverein, A G, Dortmund, Germany
75 Hoesch A G, Dortmund, Germany
76 Bochumer Verein fuer Gusstahlfabrikation A G, Bochum, Germany

Motor Vehicles and Tanks Branch

*77 German Motor Vehicles Industry Report
*78 Tank Industry Report
79 Daimler Benz A G, Unterturkheim, Germany
80 Renault Motor Vehicles Plant, Billancourt, Paris
81 Adam Opel, Russelheim, Germany
82 Daimler Benz-Gaggenau Works, Gaggenau, Germany
83 Maschinenfabrik Augsburg-Nurnberg, Nurnberg, Germany
84 Auto Union A G, Chemnitz and Zwickau, Germany
85 Henschel & Sohn, Kassel, Germany
86 Maybach Motor Works, Friedrichshafen, Germany
87 Voigtlander, Maschinenfabrik A G, Plauen, Germany
88 Volkswagenwerke, Fallersleben, Germany
89 Bussing NAG, Brunswick, Germany
90 Muehlenbau Industrie A G (Miag) Brunswick, Germany
91 Friedrich Krupp Grusonwerke, Magdeburg, Germany

Submarine Branch

92 German Submarine Industry Report
93 Maschinenfabrik Augsburg-Nurnberg A G, Augsburg, Germany
94 Blohm and Voss Shipyards, Hamburg, Germany
95 Deutschewerke A. G, Kiel, Germany
96 Deutsche Schiff und Maschinenbau, Bremen, Germany
97 Friedrich Krupp Germaniawerft, Kiel, Germany
98 Howaldtswerke A. G, Hamburg, Germany
99 Submarine Assembly Shelter, Farge, Germany
100 Bremer Vulkan, Vegesack, Germany

Ordnance Branch

*101 Ordnance Industry Report
102 Friedrich Krupp Grusonwerke A. G Magdeburg Germany
103 Bochumer Verein fuer Gusstahlfabrikation A G, Bochum, Germany
104 Henschel & Sohn, Kassel, Germany
105 Rheinmetall-Borsig, Dusseldorf, Germany
106 Hermann Goering Werke, Braunschweig, Hallendorf, Germany
107 Hannoverische Maschinenbau, Hanover, Germany
108 Gusstahlfabrik Friedrich Krupp, Essen, Germany

OIL DIVISION

*109 Oil Division, Final Report
*110 Oil Division, Final Report, Appendix
*111 Powder, Explosives, Special Rockets and Jet Propellants, War Gases and Smoke Acid (Ministerial Report #1)
112 Underground and Dispersal Plants in Greater Germany
113 The German Oil Industry, Ministerial Report Team 78
114 Ministerial Report on Chemicals

Oil Branch

115 Ammoniakwerke Merseburg G m b H, Leuna, Germany—2 Appendices
116 Braunkohle Benzin A G, Zeitz and Bohlen, Germany Wintershall A G, Leutzkendorf, Germany
117 Ludwigshafen-Oppau Works of I G Farbenindustrie A G, Ludwigshafen, Germany
118 Ruhroel Hydrogenation Plant, Bottrop-Boy, Germany, Vol, I, Vol. II
119 Rhenania Ossag Mineraloelwerke A G, Harburg Refinery, Hamburg, Germany
120 Rhenania Ossag Mineraloelwerke A G, Grasbrook Refinery, Hamburg, Germany
121 Rhenania Ossag Mineraloelwerke A G, Wilhelmsburg Refinery, Hamburg, Germany
122 Gewerkschaft Victor, Castrop-Rauxel, Germany, Vol. I & Vol. II
123 Europaeische Tanklager und Transport A G, Hamburg, Germany
124 Ebano Asphalt Werke A G, Harburg Refinery, Hamburg, Germany
125 Meerbeck Rheinpreussen Synthetic Oil Plant—Vol. I & Vol. II

Rubber Branch

126 Deutsche Dunlop Gummi Co., Hanau on Main, Germany
127 Continental Gummiwerke, Hanover, Germany
128 Huels Synthetic Rubber Plant
129 Ministerial Report on German Rubber Industry

Propellants Branch

130 Elektrochemischewerke, Munich, Germany
131 Schoenebeck Explosive Plant, Lignose Sprengstoff Werke G m b H, Bad Salzemen, Germany
132 Plants of Dynamit A G, Vormal, Alfred Nobel & Co, Troisdorf, Clausthal, Drummel and Duneberg, Germany
133 Deutsche Sprengchemie G m b H, Kraiburg, Germany

OVER-ALL ECONOMIC EFFECTS DIVISION

134 Over-all Economic Effects Division Report
Gross National Product
Kriegseilberichte
Herman Goering Works
Food and Agriculture
} Special papers which together comprise the above report
134a Industrial Sales Output and Productivity

PHYSICAL DAMAGE DIVISION

134b Physical Damage Division Report (ETO)
135 Villacoublay Airdrome, Paris, France
136 Railroad Repair Yards, Malines, Belgium
137 Railroad Repair Yards, Louvain, Belgium
138 Railroad Repair Yards, Hasselt, Belgium
139 Railroad Repair Yards, Namur, Belgium
140 Submarine Pens, Brest, France
141 Powder Plant, Angouleme, France
142 Powder Plant, Bergerac, France
143 Coking Plants, Montigny & Liege, Belgium
144 Fort St. Blaise Verdun Group, Metz, France
145 Gnome et Rhone, Limoges, France
146 Michelin Tire Factory, Clermont-Ferrand, France
147 Gnome et Rhone Aero Engine Factory, Le Mans, France
148 Kugelfischer Bearing Ball Plant, Ebelsbach, Germany
149 Louis Breguet Aircraft Plant, Toulouse, France
150 S. N. C. A. S. E. Aircraft Plant, Toulouse, France
151 A. I. A. Aircraft Plant, Toulouse, France
152 V Weapons in London
153 City Area of Krefeld
154 Public Air Raid Shelters in Germany
155 Goldenberg Thermal Electric Power Station, Knapsack, Germany
156 Brauweiler Transformer & Switching Station, Brauweiler, Germany
157 Storage Depot, Nahbollenbach, Germany
158 Railway and Road Bridge, Bad Munster, Germany
159 Railway Bridge, Eller, Germany
160 Gustloff-Werke Weimar, Weimar, Germany
161 Henschell & Sohn G m b H, Kassel, Germany
162 Area Survey at Pirmasens, Germany
163 Hanomag, Hanover, Germany
164 M A N Werke Augsburg, Augsburg, Germany
165 Friedrich Krupp A G, Essen, Germany
166 Erla Maschinenwerke G m b H, Heiterblick, Germany
167 A T G Maschinenbau G m b H, Mockau, Germany
168 Erla Maschinenwerke G m b H, Mockau, Germany
169 Bayerische Motorenwerke, Durrerhof, Germany
170 Mittel-Deutsche Motorenwerke G m b H, Taucha, Germany
171 Submarine Pens Deutsche-Werft, Hamburg, Germany
172 Multi-Storied Structures, Hamburg, Germany
173 Continental Gummiwerke, Hanover, Germany
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